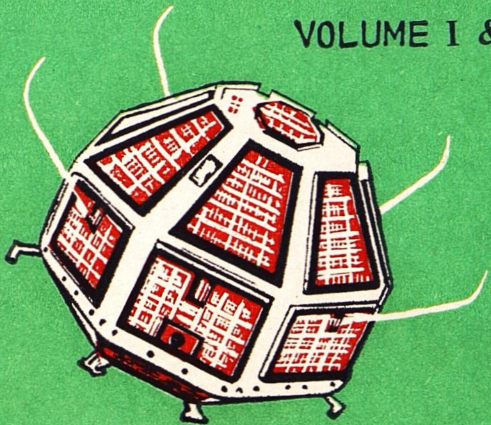
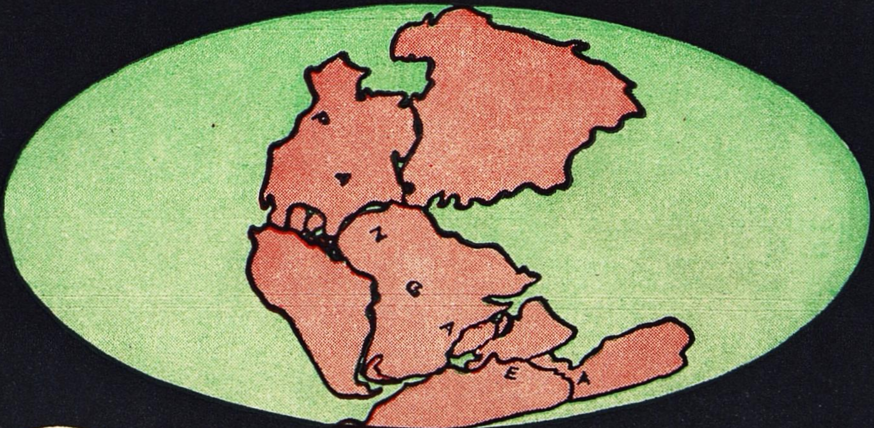
GEOGRAPHY

HIGHER SECONDARY _ FIRST YEAR

VOLUME I & II





TAMILNADU TEXTBOOK SOCIETY

GEOGRAPHY

Vol. I & II

HIGHER SECONDARY—FIRST YEAR

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MADRAS

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CHAPTER I

THE UNIVERSE

The Universe consists of millions of Galaxies which move at high speed through space. Each of these galaxies comprises of countless stars. Normally very few of the galaxies are visible to the naked eye. So far a thousand millions of galaxies have been seen by the astronomers using latest telescopes.

GALAXY

One of the millions of galaxies is the Milky Way Galaxy. This consists of millions of stars all closely packed together. The milky way galaxy is an elongated disc. It has a diameter of 1,00,000 light years. The Solar System to which our earth belongs, is located in the outer perimeter of this galaxy at a distance of 30,000 light years from its centre. (Fig. 1.1)

THE SOLAR SYSTEM

The Sun is the centre of the Solar System. Nine other planets revolve round the Sun in their orbits. The Sun is the smallest of the millions of stars in the Milky Way Galaxy. It is also the star nearest to the earth.

MEMBERS OF THE SOLAR SYSTEM

The Solar System (as we have already seen) consists of nine planets which revolve around the Sun. Mercury is the closest and Pluto is the farthest. Mercury is followed by Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune in the order of increasing distance from the Sun. The four Planets Mercury, Venus, Earth and Mars are called the inner planets as they are closer to the Sun. Jupiter, Saturn, Uranus, Neptune and Pluto are known as outer planets. (Fig. 1.2). Jupiter is the largest planet next only to the Sun. In between Jupiter and the Sun lies Mars, Earth, Venus and Mercury, while towards the outer margin of the Solar System are Saturn, Uranus, Neptune and Pluto. The size of the planets diminishes on either side from Jupiter (Table 1.1) (Fig. 1.3).

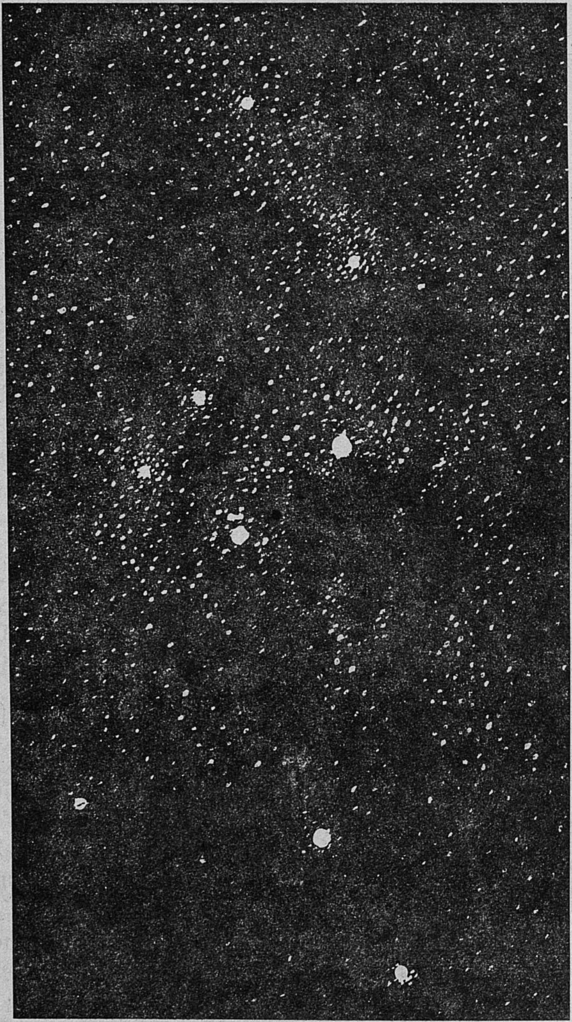

FIG. 1.1 The Milky Way Galaxy

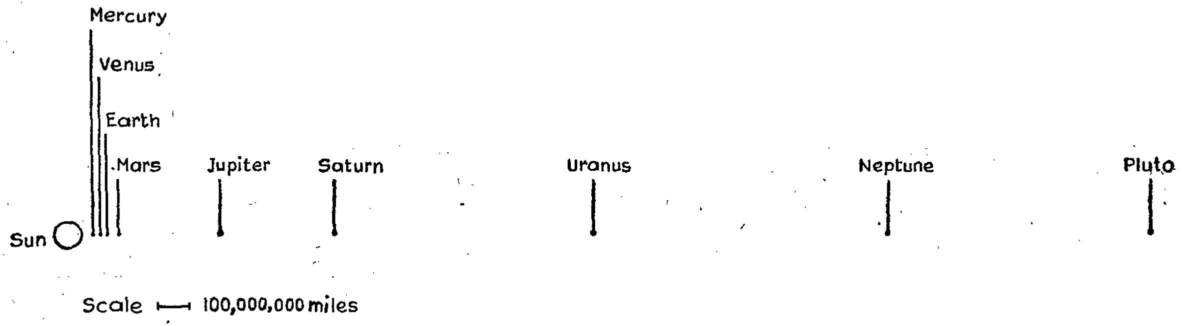

FIG. 1.2 The average distance between the sun and the other planets

TABLE 1.1

The Planets

Name of planets	Mean distance from the sun (in million miles)	Mean diameter (in miles)	Density	Time taken for one rotation	Time taken for one revolution around the sun	Number of satellites (known)
Mercury ...	36	3000	5.5	88 days	88 days	0
Venus ...	67	7600	5.1	About 1 month	225 days	0
Earth ...	93	7913	5.5	$23^h\ 56^m$	365.25 days	1
Mars ...	142	4200	3.9	$24^h\ 37^m$	656 days	2
Jupiter ...	483	87000	1.34	$9^h\ 55^m$	12 years	12
Saturn ...	886	75000	0.70	$10^h\ 29^m$	29.5 years	9
Uranus ...	1783	30000	1.40	$10^h\ 42^m$	84 years	5
Neptune	2794	29000	2.2	$15^h\ 48^m$	165 years	2
Pluto ...	3670	small	not known	16^h	248 years	not known

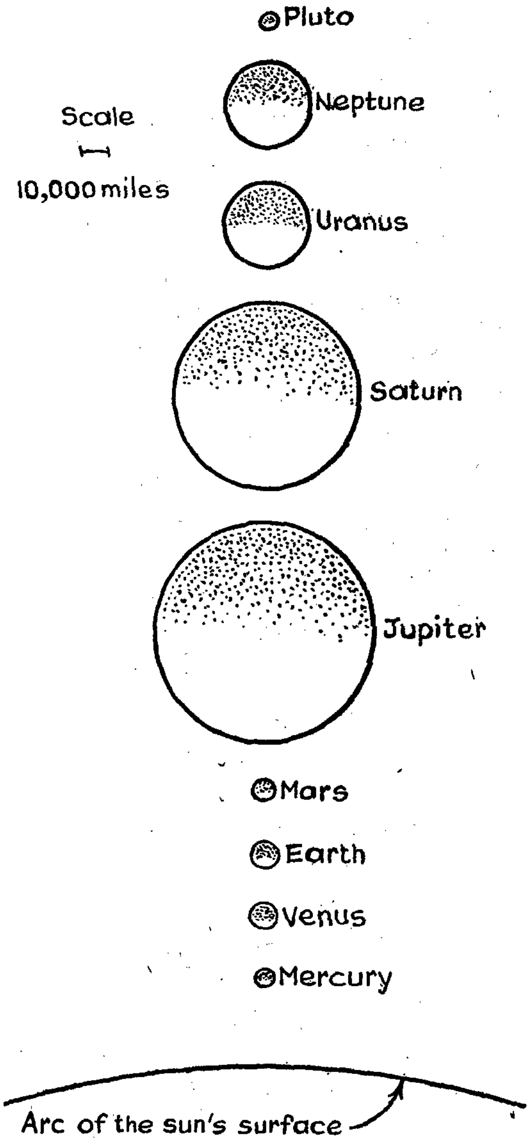

FIG. 1.3 The size of the planets in the Solar System

THE SUN

When compared to the planets, the Sun is greatly massive; because of its massiveness, the Sun is very firmly fixed in the centre. Hence the whole system is called the Solar System. The Sun which is the source of heat energy of the Solar System has vast storages of hydrogen at its core. It brings out to the surface large quantity of hydrogen and converts this into helium, thus emitting heat. The temperature at its core is 14,000,000° C. At its surface its temperature is approximately 6,000° C. The Sun ejects tongues of heat from its surface which can be seen through a solar telescope. Mercury, Venus, Earth and Mars, the inner planets, resemble each other in many ways. They have a higher proportion of elements like silicon, iron, manganese etc. Mercury is the nearest planet to the Sun. It has more heavier elements than earth and venus. Mercury takes 88 days to complete one revolution and 55 days to complete a rotation. Venus is much alike the earth in size and internal composition. But its surface temperature ranges between 400° C and 530° C. It has a carbon-dioxide atmosphere. Mars which is a small reddish planet, rotates once in 24½ hours and has two satellites. It is believed to have a small iron core. After Mars, a wide belt of thousand of small asteroids and planetoids exists. At least 50,000 of them are large enough to be photographed. The largest of them, Celes, has a diameter of 429 miles. The second largest, Pallas, has a diameter of 281 miles. Jupiter has a mass of one-thousandth of the mass of the Sun. This largest planet in the Solar System has an equational diameter of 87,000 miles and flattened poles. The core of Jupiter is believed to possess high temperature and pressure. It may consist of metallic hydrogen or heavier elements. The atmosphere of Jupiter contains ammonia, methane and water; all the elements are present in the form of ice crystal. Jupiter has 12 satellites, the largest number of satellites any planet in the Solar System possesses. Saturn is the second largest planet in the Solar System. It has a diameter of 75,000 miles. It has rings around it consisting of ammonia ice crystalls. The Saturn rotates, and completes one rotation in 10 hours 14 minutes. The surface temperature of Saturn is about—290° F (—143° C). Beyond Saturn are two planets, Uranus and Neptune. They possess similar characteristics like Saturn and Jupiter. Uranus has a density of 1.65 and has a

surface temperature of $-310°$ F ($-154°$ C). Its atmosphere is believed to contain methane and ammonia. Uranus has two satellites. Neptune's atmosphere is also believed to contain methane and ammonia. Its surface temperature is around $-360°$F ($-181°$ C) and lower.

Pluto is the most distant planet and also the most recently discovered planet. Nothing much is known about Pluto. Its diameter is believed to be greater than 3,700 miles.

THE EARTH

The Earth, the abode of man, is the third planet from the Sun, next to Mercury and Venus It is also the fifth largest planet of the Solar System, next to Jupiter, Saturn, Uranus and Neptune. The Earth is 93 million miles away from the Sun.

Movements of the Earth

The Earth has two major movements. They are rotation and revolution. It rotates on its axis and revolves around the Sun. These two types of movements are largely responsible for such important phenomena like the unequal distribution of solar energy, various seasons on the surface of the earth and climatic differences.

Rotation

The Earth is completing one rotation in 23 hours and 56 minutes. The speed of rotation at the equator is 1,041 miles per hour and it decreases almost to zero at the poles, This rotation of the earth results in one portion of its surface receiving solar energy and light for a particular period whereas the other portion facing away from the sun will be in darkness for that period. The boundary line that separates the dark and light portions of the surface of the earth is called the Circle of Illumination.

Revolution

The Earth revolves round the sun once in 365.25 days. It follows an elliptical path at an average distance of 96 million miles from the Sun. The farthest distance is 94½ million miles (aphelion) and the nearest distance is 91½ million miles (perihelion). The speed of revolution is greatest during perihelion and least during

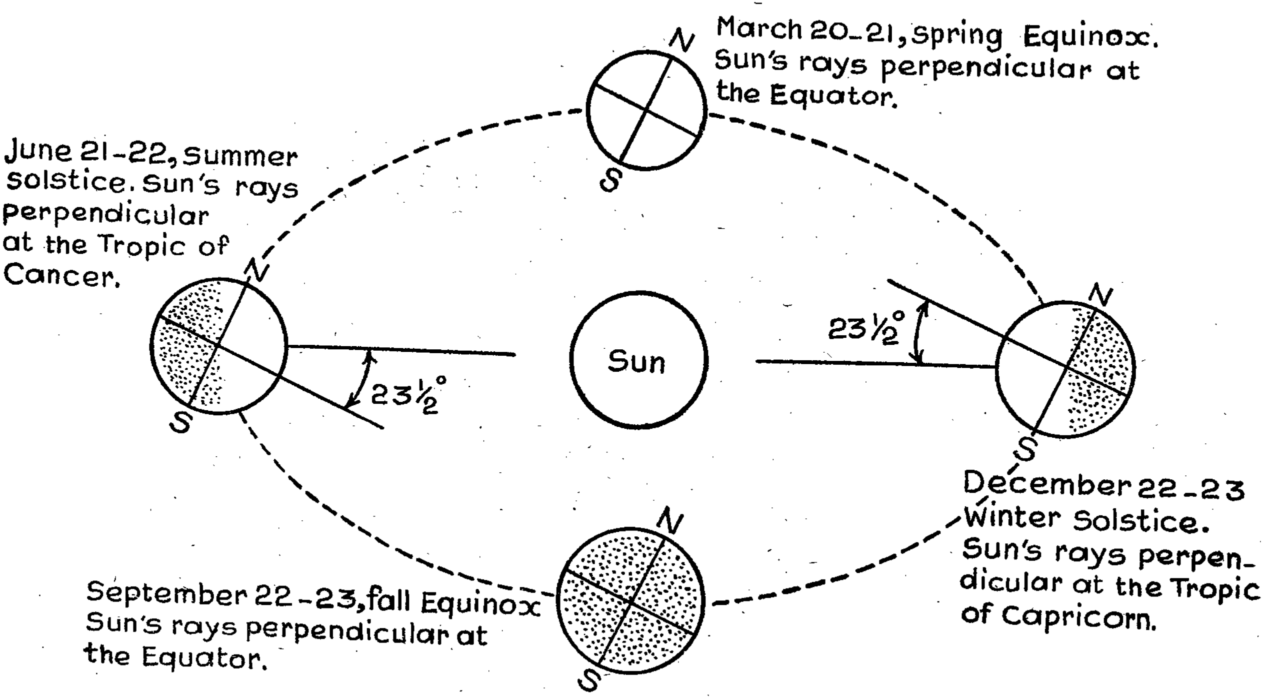

FIG. 1.4 The inclination of the earth's axis and seasons

aphelion. The average speed of revolution is 70,000 miles per hour.

Effects of Rotation and Revolution

As the earth rotates on its axis, it also revolves round the Sun. Its axis, while rotating by itself and revolving around the Sun is inclined at an angle of 23½% to the plane of the earth. This angle of inclination of the earth's axis never changes. This causes differences in the length of day and night from place to place and also from season to season (Fig. 1.4).

Equinoxes

As the earth rotates and revolves with an inclined axis, the Sun migrates between the Tropics of Cancer and Capricorn once in a year. During this period it crosses the equator twice. The sun will be vertically overhead on the equator on March 20–21 and September 22–23. During this time, days and nights are of equal length over the earth. These periods are described as Equinoxes. (Fig. 1.5)

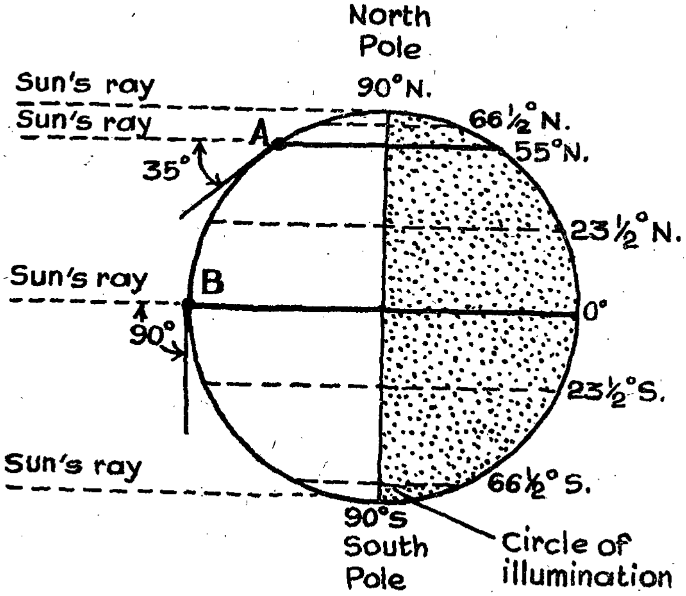

FIG. 1.5 Falling of vertical rays of the Sun on the Equator and the Equinoxes

Solstices

The Sun will be directly overhead on the Tropic of Cancer on June 21-22. During this period the areas enclosed by the Arctic Circle (66½°N) will enjoy day light for 6 months. Whereas the area enclosed by Antarctic Circle (66½°S) will have six months of darkness. This is known as the Summer Solstice. Likewise on December 22-23 the Sun will be vertically overhead on the Tropic of Capricon. Now the Southern Hemisphere will experience summer, while the Northern Hemisphere will enjoy its winter. Areas surrounding the South Pole as enclosed by Antarctic Circle will have a six month period of day light, and the reverse will obtain at the North Pole. This is known as the Winter Solstice (Fig. 1.6).

MOON

The Moon is the satellite of the planet, Earth. It is greater in size comparatively to the size of the earth. The earth and the moon are described as double planet system. The moon is said to be revolving round the earth as it rotates. Actually the earth and the moon rotate and revolve together around a common centre of gravity. This common centre of gravity, called the barry centre, lies within the earth itself, 1700 kms. inside from its surface. They are held in their position, by their material force of gravitational attraction. The moon follows an elliptical orbit and revolves around the earth. The average diameter of its orbit is 3,84,400 kms. The temperature conditions are of extreme type on the surface of the moon. At noon the temperature rises to 218°F (103° C); but at midnight it falls to—157°C (—250°F). In addition the surface of the moon is bereft of an atmosphere. Hence the lunar surface presents a highly inhospitable condition.

It is 3,480 kms. in diameter. It has a surface area of 38 mi. sq.kms. (Compare this with that of the earth).

Motions of the Moon

The moon rotates on its own axis and revolves round the earth. It takes nearly 24 hours 51 minutes to complete one rotation and 27 days and 8 hours to complete one revolution.

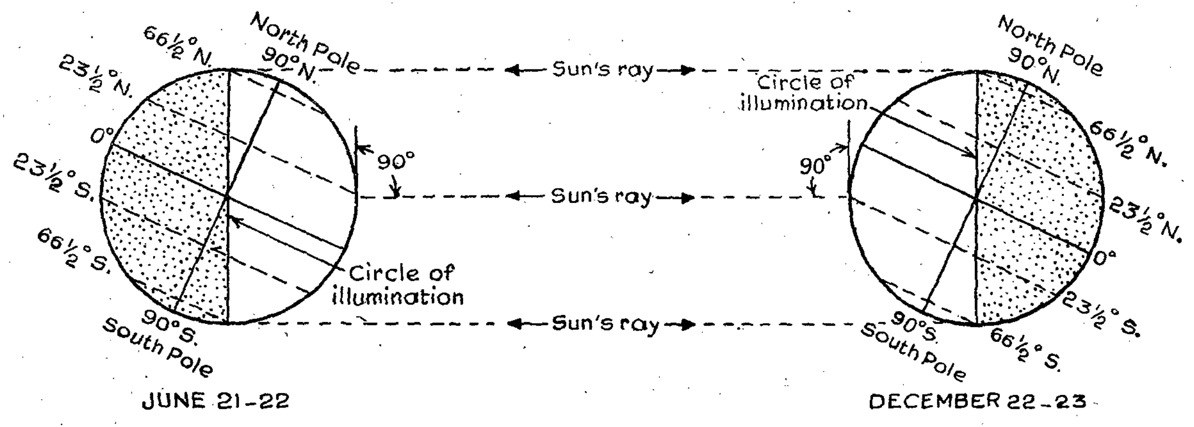

FIG. 1.6 Summer and Winter Solstices

Surface of the Moon

To our naked eyes the Moon seems to have brighter and darker patches on its surface. The brighter patches are the mountains and portions of craters. The darker patches are the lowlying areas and plains. The mountains rise to relatively higher elevations of up to 20,000 ft. and likewise the plains and craters which abound in large numbers, sometimes stretch to a diameter of 150 miles and more. The craters seem to be either volcanic or meteoric in origin. A typical characteristic of the moon is the absence of water in it. It does not possess an atmosphere. It is presumed that the gravity of the moon is just 1/6 of that of the earth. Hence it is not able to hold gases to form its atmosphere. The absence of atmosphere explains the extremes of temperature conditions.

Faces of the Moon

The speed of rotation of the moon is almost the same as that of the earth. Because of this, the moon always presents only one side of its surface to the earth. The other half of the moon is never visible to us on earth. It is also well-known that the moon does not have its own light. It only reflects sun's light, which is called the moon light.

The Phases of the Moon

As moon is a spherical object like earth, only one half surface of the moon receives sun light at a time. The other half remains in darkness. They are called the lunar day and lunar night respectively. The revolution of moon round the earth brings into view varying portions of the lighted surface of the moon. These are described at the 'phases of the moon'. While revolving round, the moon comes into a middle position between the earth and the sun. This position is called 'conjunction'. At this position the lit portion of the moon will be facing away from the earth. (Fig. 1.7.). This is known as the New Moon Day or No Moon Day. Two weeks later the moon once again falls in a straight line, when the earth occupies the middle position. Now the moon is said to be in opposition. Now its lit-surface will be facing the earth. This is known as the Full Moon Day. During these fourteen days the proportion of the lit-surface of the moon will be on the

increase. This is described as the Waxing of the Moon. Likewise the full moon goes through a period of two weeks gradually getting reduced in the proportion of its lit surface before reaching the New Moon position once again. This part of the phase of the

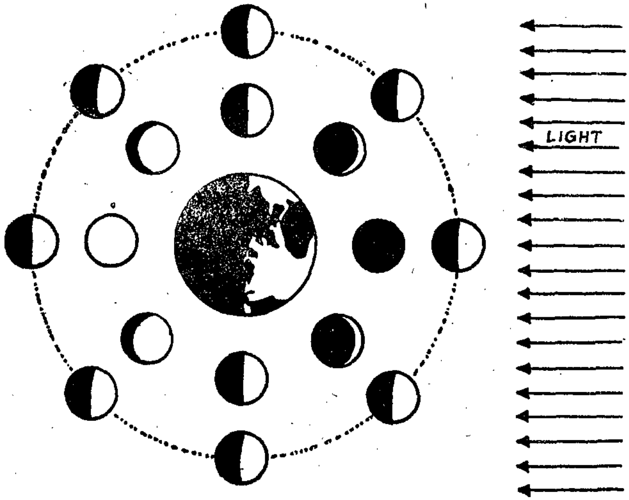

FIG. 1.7 Phases of the Moon

moon is known as the Waning of the moon. During the waxing period the moon goes through New Moon, Cresent, half and gibbous phases, while during waning period it goes through the gibbous, half and crescent phases. During the half moon days the moon will be at right angles to the sun. These positions are described as Quadratures.

ECLIPSES

The celestial bodies are all spherical in shape. As they move in their respective orbits they cast long, tapering and cone-like shadows. Normally these shadows are not visible to us (Fig. 1.8). But when any celestial object passes through the shadow, the object is said to eclipse. The eclipses are of two types. They are the solar eclipse and lunar eclipse. When the sun, the earth and the moon are in a straight line, eclipses occur. This obviously means that the solar and lunar eclipses occur only during the new moon day (solar eclipse) and full moon day (lunar eclipse).

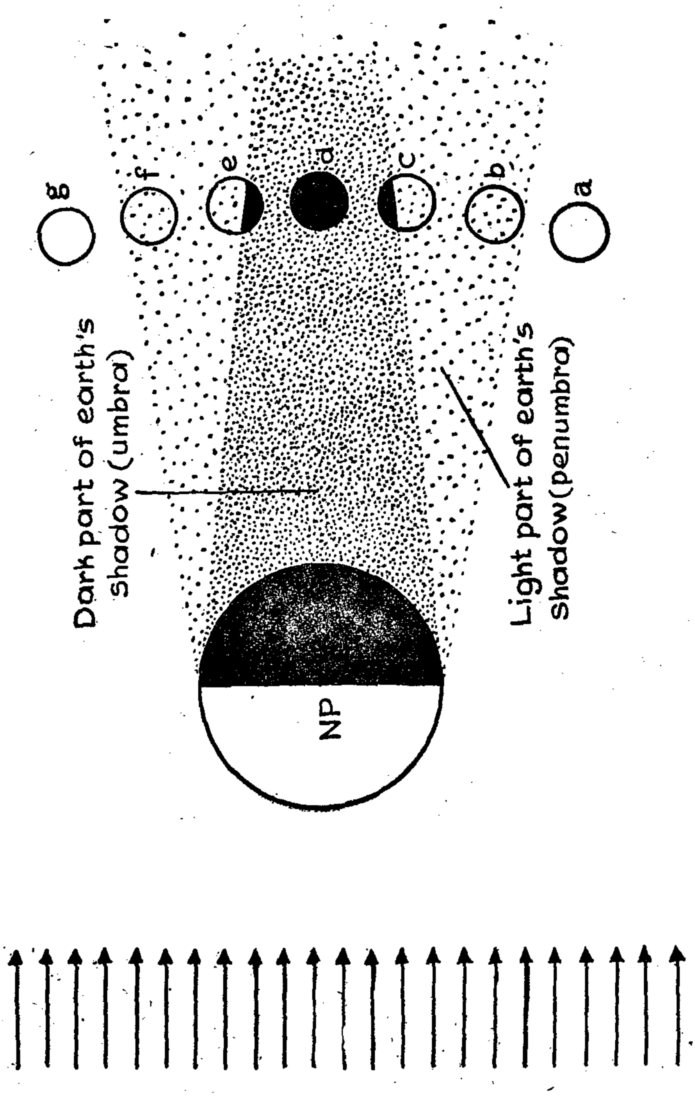

FIG. 1.8 Lunar eclipse

Solar Eclipse

As the moon occupies the middle position between the earth and the sun, the moon blots out the sun from the earth, thus causing solar eclipse. Solar eclipses are a rare phenomena and it does not occur during every new moon day.

Lunar Eclipse

During lunar eclipses the earth occupies the middle positior thus blotting out sun's light from reaching the moon. Lunar eclipses are more frequent than the Solar eclipses. They are visible to those on the night time side of the earth.

ORIGIN OF THE SOLAR SYSTEM

Many theories have been put forward for the origin of the Solar System But none of them have been found to be satisfactory so far. The members of the Solar System rotate as well as revolve with a precise regularity and uniformity. This may be considered as indicating at least that they might have originated more or less at the same time and the same manner. And they are also supposed to have formed a part of the sun.

Kant and Laplace

The earliest theories have been propounded by Kant and Laplace. These theories are known as nebular hypothesis. They suggested that the entire Solar System was once a great mass of hot and gaseous cloud called the ' Nebula ' which was rotating slowly to begin with. It started cooling down gradually which resulted in its shrinking. This made the nebula to rotate rapidly. Cooling, shrinking and rapid rotation all put together developed a ring of gaseous material around the core. The core shrank still further and started rotating still more rapidly. In this process the ring was thrown out and the scattered materials formed into satellites. Then the nebular hypothesis suggests the planets were first gaseous, and finally have become solid.

Tidal Theories

Recently Jean and Jeffreys have put forward different theories. These theories suggest that the planets were ejected from

the sun or a larger star which might have passed by. It was proposed that the encounter of these stars might have produced tidal effects on their surfaces, resulting in the ejection of materials. These materials have later solidified into planets and satellites.

Apart from these many more new theories have been put forward to explain the origin of the Solar System. But none of them satisfactorily explains the origin of the Solar System.

QUESTIONS

I. Short answer questions :

1. What is a galaxy?
2. Define Solar System.
3. What are the inner planets?
4. State the important characteristics of the Sun.
5. State the effects of rotation and revolution of Earth.

II. Long answer questions :

1. Give a comprehensive account of the Solar System.
2. How seasons are caused? Explain.

CHAPTER II

MAN AND SPACE

The single and outstanding factor in the entire Universe is man. He is the highest representation of the order of primates. He has explored and discovered myriads of things of Science on the Land, Sea and Space of physical laws, that unravel the mysteries of this universe to promote Science and Technology in the Service of man and his well-being. It is equally significant that he probes into human nature and stimulates human compassion that recognizes tolerance as the highest and fundamental of all that measures human values and humanizes man in a world of natural, physical and biological unity and diversity.

Probing into space, man has spaned the third dimension for expansion. The first pictures of the Earth from space, brought home to man the realization that the Earth is of immeasurable value in that it holds life. All living things, including human beings, land and sea animals and microbes made the earth awe inspiring and give promise of hope for the future. It has now come to man as a revelation that because of this the Earth must be saved for humanity.

The decade of sixties will go down in human history as the decade not only of space exploration but also as a never before experienced race of super powers on Earth for prestige on land, sea and space. This race could lead to annihilation of Mankind and his civilization if not governed by reasoned application of Science and Technology.

DIVIDENDS FROM SPACE

The Satellites that encircle the earth have brought into reality the promises of dividends from space. The inhabitants on the Earth will benefit from space contributions through a wide range of products useful for homes, for man's health medicine

and industry. Besides, the satellites have opened up multifarious channels for research programmes through observations from space and communications on earth from space. In fact space effects have given challenge to problems of human life in a manner that is bewildering and would appear to be endless.

THE WORLD—HUMAN CIVILIZATION

One important resource of the Earth is land. The entire land surface with its wealth of geographical environments is inhabited by nearly four billion people, men and women who make the human races, recognized in groups varied with different cultures, languages and different institutions or organizations. Human History is a long narrative of conflicts between man and states for territorial gains and power. Nevertheless humanity built up high civilizations of great complexity. These are to be protected, further developed and saved for the human progeny.

A WORLD OF PEACE

A civilized world can be developed in a world of peace and most enlightened statesmen of the world are working towards a world of peace. Race prejudice, national jealousies and power to dominate the world, reduce the prospects for world peace to materialize. Race prejudice is due to ignorance. Love of power and jealousy are due to lack of understanding the brotherhood of man. Geographically oriented studies of Environment and Man will help to eleminate all prejudices of race and Nations. Studies grafted to teaching Geography of religions will lead to progress in building up a world towards peace.

In the solutions to reconcile the various problems confronting humanity, there should be a total transformation in values of human life. Man has got to be changed from a selfish self-oriented to self-less universal brotherhood-oriented. We must know how to humanize humanity. This process of humanizing humanity must start with the individual from within, that is from the heart of man.

HOPE OF MANKIND

Peace has been the greatest quest of mankind through the ages. A world government has been proposed as a solution to world peace and a hope of mankind. The idealogical conflicts with regard to methods to solve problems of poverty, oppression, prejudices, etc. pervade both the developed and developing nations. The U.N.O. contains the neucleous within itself for the World Government to achieve peace.

BIOSPHERE

The biosphere is the most significant part of the earth. I sustains all living things and is a unique shelter for man in the vast universe

It comprises of the lowest stratum of the restless atmosphere, top layers of the wavy hydrosphere and the thin microscopic film of the living complex of productive and sustaining lithosphere, the zone of overwhelming interest to the microbiologists. The five natural elements, the sun, light, air, water and earth have conjugated righteously to create this Home of Man.

This narrow, interrupted thin crust supports nearly 4 billion human beings on the 25 million sq. miles in thousands of human agglomerations situated mostly between 0′ to 5,000′ above sea level. Our knowledge of this living world has grown through human intellect, curiosity, travel, exploration of the spirit of discovery of man who baffled with immensity on the boundless space and the mystery of our neighbours in space. However, man finds solace on the 'Terra Firmma' the Earth below his feet. He (man) stands only 5.ft 6 inches from the ground. The multiplicity of the evolution and diversity of all the living things, enrich his geographical environments.

Yet this living zone is the narrow strip that supports the tall trees that grow to a height of 200 feet. The awe inspring acquiera in California grows up to only 250 ft. In the animal world the tallest animal giraffe due to the elongation of its neck as a special adaptation of its habit stands only 10 feet above surface. Life

in seas and oceans is also confined to an equally narrow zone. Whether fish or whale they are found between the S.L. and 1,000 feet. Life in the atmosphere does not go beyond 1,000 feet. The common birds do not fly beyond a few hundred feet. Even the eagle does not soar higher than 600 feet. Our giant planes fly below 30,000 feet.

On the surface of the earth the wide range of edible plants that man grows, penetrate their roofs up to 20 inches only. The soil teeming with microscopic organisms, insects, and worms which make life on this plant are but a few inches thick. The soil is indeed a thin outer layer of the crust to be treated with care and regard. Man can destroy soils beyond redemption if he makes wrong decisions. Through out history of man, land had been the most sought after possession but one of the least understood of the earth's phenomena. Land is wealth, and not a mere something to satisfy a demand to grow food or find living space. Rarely land has been treated as a living entity or a resource of limited supply. It provides habitable and cultivable land Vast areas are now converted into non-productive areas by buildings and development of settlements, towns, industries, roads, factories, and store houses for the benefit of men.

The earth's crust is a realm of constant change and this has been so all through its history in time and space. The climate of the globe has experienced changes throughout the Geological ages, alternating between warm and cold periods. Now the world is said to be returning from the cold to normal climatic condition. In the last quarternary ice age, the biosphere has witnessed the most spectacular event.

Emergence of Man

The evolution of man from the anthropoid stage is said to have taken place in the past quarternary period. Man stood erection in the biosphere some 50,000 years ago. For more than a quarter million years he was a primitive hunter and food gatherer and used stone tools. He was at a mere subsistance level and progress was slow. He learnt the art of growing crops about 10,000 years ago, when he started a settled life. With this civilization began. According to the geographical environments and the resources, man developed arts and crafts and learnt the art

of producing food at will and to master his environment with his intellect and skill. His progress accelerated in every direction and he began to multiply to spread and to migrate on the earth in different direction. The geographical environments cast mankind into distinctive types different from one another in skin, colour and other physical characteristics, like stature, cephalic and nasal indices. Man rose from simple rural self-sufficient level. Propelled by science and technology he advanced in industry and trade which brought indelible changes. By 19th century Urbanization perceptably transformed the biosphere, with a civilization with mixed benefits. Impacts of competition, crime, poverty, pollution, urban strains and stresses, leading to moral degeneration, overpowered the biosphere.

WORLD NATIONS

The biosphere supports the 4 billion human beings belonging to 145 nations. Some nations that profited from environmental advantages, wealth and power while others are reduced to want and hunger. Yet he multiplied and increased in numbers at phenomenal growth rates which sharpened the differences between the ' haves and have nots ' on the biosphere. Widening the gap, that is a challenge to civilization. Has the biosphere accepted this challenge to prevent Science and Technology to lead mankind to global wars, and extinction of human race ?

The rising tide of colour along with the impact of the Socio-Cultural changes are making themselves felt. The United Nations which emerged as the voice of the Free World is often baffled. The U.S.A and U.S.S.R. are now accepted as super powers representing democracy and socialism while some have fallen in under these two, other profess neutralism. India is one which is said to remain the third world, less developing, neutral in world politics. All the others are grouped to form countries whose security and economy are swayed by super powers.

EARTH AS THE HOME OF MAN

The Earth's environments are bountiful each in its own way in physical beauty, in the wealth of their resources, productivity and population which can culturally be classified into groups,

tribal, traditional or modern. They are widely scattered and varied in habitat, economy and society in their development from simple food gathering—hunting stage through subsistance farming, shifting cultivation to multiple agriculture with livestock, to plantation, culture, commerce and industry. The Earth as the Home of Man, provides for all types and economic levels from extremely simple to highly complicated commercial patterns and for all people in all walks of life.

Modern transport is annihilating distances. To day remote people are our close neighbours. As the globe is shrinking, life activities are changing and developing, culture groups are transforming and tools of man are also evolving. The commerce-industry based groups are spreading all over the globe and the impact of trade and commerce is felt universally.

BASIC WANTS OF MAN

Of the basic wants of man, shelter is constructed or made generally using the materials locally available in the environment. The genius of man is brought out in using the indegenous materials in designing or shaping them to his advantage.

Whether it is the igloo of the Eskimo in the polar regions or the fragile huts on the bamboo stilts along the tidal coasts of tropical Borneo or the tree-houses on the branches of tropical trees reached by a ladder, or the caves that were dug out of the massive loess in North China or limestones in Italy, or the dwellings in the boat-houses in Hong Kong or Tierre del Fuego man needs protection from harsh climates and inhospitable environments.

Again whether he is an occupant of the sophisticated flats in the Sky scrapers of New York or an elegant Villa on the coasts of the French Reviera on the Mediterranean, man next to food needs shelter which he makes. It is an adaptation that reflects the geographical environment.

While the mobility of man, civilization and modern conveniences of transport places the whole world within his reach that

he can make his home in any part of the Globe ; still man loves his home-land which has a peculiar hold on man that we say 'East is East and West is West but to Most of us home is Best.'

QUESTIONS

I. Short answer questions :

1. Define the One World Concept.
2. What do you know about Space?
3. What are the basic wants of man ?
4. Define Biosphere.
5. What do you mean by dividends from Space ?

II. Long answer questions :

1. Explain the importance of Biosphere.
2. Earth as the home of man.—Expand.

CHAPTER III

LAND AND SEA

Origin of the Earth

The early religious concept held by Egyptians and Babylonians regarding the origin of the earth was that supernatural powers created the earth and the heaven out of chaos or unorganised matter. According to the Old Testament of the Bible, God created light first and the different organisms and ultimately man. He ordained the Sun, the Moon and the Stars to provide light for man on the earth.

Regarding the origin of the earth, several theories have been put forth by scientists and others and all of these point out that the formation of the earth is closely related to the beginning of the solar system. In 1755, the German Philosopher, Kant, suggested that the earth and the other planets were formed by the condensation of a rotating nebula of hot gas, which in its original form is still represented by the hot sun. The Nebular Hypothesis was supported by the French Mathematical Laplace in 1796. According to the nebular theory, the cooling process caused the earth to form an atmosphere and a solid crust. The water vapour in the atmosphere condensed to form water.

The dust-cloud hypothesis (of Whipple) denotes that the solar system was formed from a dust stream in the dust-gas cloud. The Von Weizsacher hypothesis says that the entire solar system orginated from a huge wheeling cloud of gas and dust, about six billion years ago. The central part of the rotating mass became the sun and the clouds on the periphery condensed to form the planets of other celestial bodies, all of which were held by the gravitational pull of the sun.

The earth thus formed by anyone of the theories put fourth, forms a part of the solar system in which every one of the nine planets revolve round the Sun. To-day, the earth has six continents and five principal oceans but orginally there was only one

huge land mass, a super-continent, according to the German Geologist, Alfred Wegenar, who, in 1912, put forth this continental drift theory. The super-continent called Pangaea, meaning 'all lands' was surrounded by a universal ocean named Panthalassa. Due to geological pressure the super-continents broke up, the broken pieces drifting apart, forming separate continents in their present shape and location. However, it should be pointed out that several rifts were responsible for this. For example, in the east-west rift of the super-continent, the southern half formed the Gondwana land from which emerged Africa with Arabia, South America, Australia, Antarctica and India. Further rifts were responsible for the present shape and location of these continents and land forms. Even though this theory was disputed for some years, the research evidence on this subject since 1963, is in support of this theory. The shores of opposite continents fit together fairly well, like a zig-zag puzzle such as that of west coast of Africa and eastern coast of South America. It is generally accepted that the displaced portions of the original continent were constantly on the move, throughout their geological history and are still shiting in their present location.

LAND

Man lives mostly on the land surface of the earth and makes use of the land to supply his wants and provide facilities for his living. The land surface consists of large features, such as mountains, table lands, hills and plains, as well as smaller forms such as valleys, ridges, deltas and sandbars. All these lands forms on the land surface form only 29 per cent of the total surface of the earth. A large portion of the surface of the earth contains water-bodies. Further, the land is not continous on the surface. It is interrupted by water bodies such as seas, rivers, lakes etc. and all the continents are surrounded by oceans. Including Antarctica, which occupies the southern most point of the earth, there are six continents, the others being Asia, Europe, America, Africa and Australia.

SEA

On the surface of the earth, 71 per cent of the area is occupied by water bodies. The major oceans are the Pacific, Atlantic,

Indian and Arctic. Each ocean has within itself seas, gulfs, bays and straits. The major portion of the Indian ocean is in the Southern Hemisphere and the whole of the Arctic sea is in the Northern Hemisphere. Both the Pacific and the Atlantic oceans have their southern and northern portions in both the hemispheres. Taken in large perspective, both the oceans and the continents can be said to have a triangular shape.

The average height of the land surface, measured from the sea-level, is 840 metres whereas the average depth of the oceans is, 3,800 metres. While the high altitudes from only 1% of the earth's surface, the depth of the oceans form 25 per cent. If the earth's crust did not have any depressions and hollows to hold the water, then the existing water on the earth would stand to a height of 2,430 metres.

DISTRIBUTION OF LAND AND SEA

1. The distribution of land and sea on the surface of the earth is 29 per cent and 71 per cent, respectively. But the distribution is equal in the northern hemisphere, whereas in the southern hemisphere it is in the ratio of 1:15.

2. If the land surface occupies a large area in one part of the earth, water surface is equally large on the opposite side. The existance of the Arctic ocean in the northern hemisphere and Antarctic in the southern is a good example.

3. The largest land surface is in the northern hemisphere and it forms a girdle around the tropics.

4. It is to be noted that the continents of the southern hemisphere taper in the southern direction.

5. The three protrusions of the Antarctica continent point towards each of the three southern continents, South America, Africa and Australia.

Following are some of the major factors to be noted in regard to the distribution of land and sea on the surface of the earth:

1. Due to the presence of long and continuous land mass in the northern hemisphere, the transport systems form a grid of communication artexies. Examples of the major net-works are

the Atlantic sea routes, the trans-Siberian railway, the trans-continental railway lines of North America, and the Pacific sea routes.

2. In the northern hemisphere, the transport, trade and communication lines run east-west whereas in the southern hemisphere it is in the north-south direction.

3. The distance in between the continents in the southern hemisphere, specially Australia, is long. The continents of the northern hemisphere are closer to each other.

4. In the interior of the northern hemisphere, the range of temperature between the summer and winter months is very marked, mainly due to the lack of the moderating influences of the oceans. Countries with such high range are said to have the continental climate.

5. The spread of the southern continents is within the 55° latitude and between the southern continents and the Antarctica continent, there is a circle of oceans.

USES OF THE DIFFERENT LAND FORMS

The mountains and hills contribute to the climate of a place. The Himalayas stand as a barrier to the cold air masses from Central Asia and these prevent North India from experiencing severe winters. The south-west monsoon winds that blow in the summer from the Arabian sea are stopped by the Western Ghats, resulting in forming a rain shadow region on the eastern side of the Ghats. The hard old rocks found in the mountains and plateaus contain minerals and ores. From the ancient times, plains have supported civilizations, because of the more or less even land with water resources and the fertile alluvial soil brought down by the rivers which promote agriculture. The density of the population has been high on these plains. Man uses the waterfalls on the mountains to generate electricity. Cattle raising is the chief occupation of the people in the Savana grass lands. Similar examples can be given to illustrate the uses of the different type of land forms in variety of ways, emphasising the interdependence of man and nature.

USES OF SEAS

From the sea we get food-stuffs in terms of the different fish, sea-weed, salt, etc. and jewellery articles, such as pearls, corals and shells. Important trade and transport routes are on the seas. The moisture-laden rain clouds and land and sea breeze have their origin from the seas. The oceans have a moderating influence on their adjoining hard surfaces.

QUESTIONS

I. Short answer questions:

1. What is Pangaea?
2. What is the ratio between the land and sea?
3. What are the different uses of sea?

II. Long answer questions:

1. Give an account of the origin of Earth.
2. Explain the land and sea distribution.

CHAPTER IV

STRUCTURE OF THE EARTH

In the immense, wide and immeasurable area of space beyond the envelope of atmosphere are millions of stars, and other celestial bodies. The Sun, along with the nine planets and their 31 satellites, millions of asteroids, comets and meteroids form the Solar System. The Earth is one of the nine planets in the Solar System and the sun occupies the central position. All the planets of the Solar System, in addition to rotating on their owe axis, revolve round the sun in elliptical orbits. Due to gravitation, the planets keep to their orbits and, without colliding with each other, move around the sun. The Earth is the only planet in the system which supports living beings.

The major characteristics of the earth, such as its shape, size, volume, area, etc. have already been studied in the earlier classes. However, some of the important points are recalled to mind now, in order to comprehend the structure of the earth and understand its significance.

In shape, the earth is not a perfect sphere but is an oblate spheroid, slightly flattened at the poles, with bulging at the equator. The Earth's rotation causes day and night. Its revolution around the sun and the inclination of its axis to the plane of its orbit are the main causes for the seasons to occur. The earth takes 24 hours for one rotation and one year ($365\frac{1}{4}$ days) to revolve once round the sun. The earth is characterised by a number and variety of surface features—highlands, plateaus, steep slopes, valleys, tablelands, hills, mountain ranges—are arranged in endless combinations. Seas and oceans occupy the very low depressions in the earth's crust.

Given below are some of the measurements of the earth :—

1. Earth's Equatorial radius ... 6,378 km.
2. Earth's polar radius ... 6,357 km.
3. Earth's equatorial circumference 40,076 km.

4.	Earth's polar circumference	40,008 km.
5.	Volume	1·08×10 c. km.
6.	Mass	5·975×10
7.	Density	5·517 gram per c.cm.
8.	Highest place on earth's crust	Mount Everest 8,848 m.
9.	Deepest depth of the crust ...	Mariana Trench 11,035m.
10.	Land surface	148,892,000 sq. km.
11.	Sea surface	361,059,500 sq. km.
12.	Total surface of the earth	510,000,000 km.

INTERIOR OF THE EARTH

Earth is made up of solids, liquids and gases and as such it is being referred to as having land-surface (lithosphere) and water

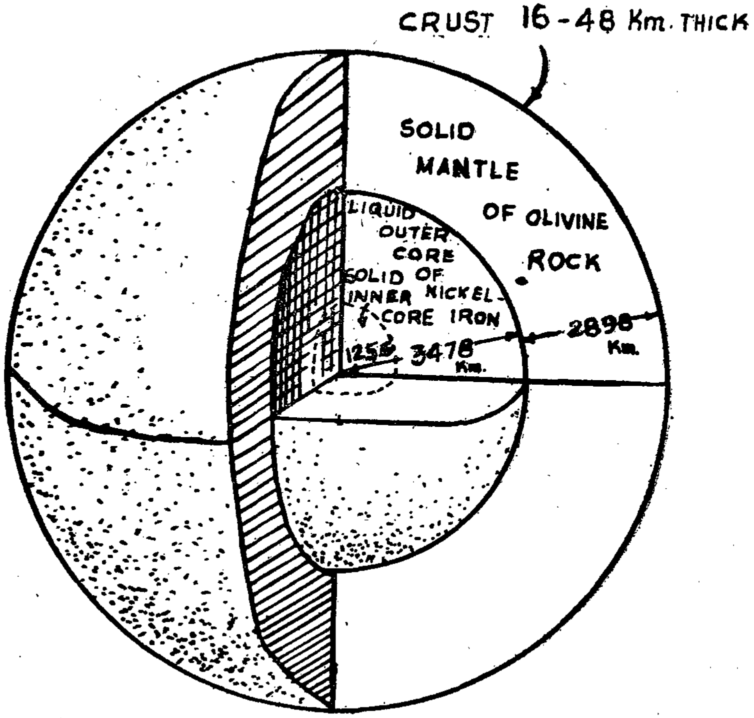

FIG. 4.1 Interior of the Earth

surface Fig. 4.1 (hydrosphere), both being enveloped by a gaseous film, the atmosphere. Much of the human activities takes place just on the outer surface of the earth and there is no need for man to understand the interior of the earth. But the forces acting within the interior of the earth, result in movements and changes that are responsible for earthquakes, volcanoes, faulting, warping, and displacements on the crust of the earth. Many of these phenomena affect the life and activities of man. Hence the need to study the interior of the earth.

We are able to observe and study some of the rock materials inside the earth, by digging deep holes for obtaining underground water or through the deep mines. So far the crust of the earth has been examined only to a depth of 6,100 meters. Earthquakes, waves, magnetism of the earth and the force of gravity enable us to study the interior of the earth.

As a result of the scientific study of the interior of the earth, it is concluded that the earth consists of:

(i) an interior part called 'The Core'.

(ii) an outer thin shell known as 'The Crust' and

(iii) a very thick layer, which is called 'The Mantle', lying between the outer crust and the interior core of the earth.

The Core

Our Earth is a very large body. It is almost spherical in shape. The diameter of the earth is about 12,750 kms. The interior central part of the earth is occupied by a spherical zone which is about 3,460 kms. in radius from the centre of the earth. It is about half the size of the earth. The zone is known as the 'Core' of the earth. As we go from the surface of the earth towards the centre, the rock materials are harder and heavier. It has been calculated that the mean density of the earth as a whole is 5.5. But the density of the rocks found on the surface of the earth is less than 3. Perhaps the density of the rock materials of the earth's core is about 12. On account of the earth's magnetism, it is believed that the core of the earth is made up of a mixture of iron and nickel. The core may be subdivided into two parts. The

inner parts of the core are believed to be in a solid state, up to a distance of about 1,380 kms. from the centre. The rest of the core (the outer zone) is believed to be in a liquid state. Although the term liquid is used here, yet, we should not take it to be like any liquid matter known to us on the surface of the earth. The core of the earth is not only extremely dense but also very hot. The temperature of the core may range from about 1,900°C to about 4,200°C.

The Mantle

Outside the Core lies a layer which is about 2,880 kms. in thickness. This layer is called. The Mantle of the earth. It is believed to be made up of a mineral called Olivina. The Mantle is resting on the outer ' liquid ' part of the earth's Core. This zone behaves like a liquid when earthquake waves reach it, by deflecting the waves away from the centre of the earth. At such great depth, with such a high temperature of about 2,200° C, and with such a heavy mass of rock materials pressing down upon it, we cannot describe exactly the nature of the 'liquid' part of the earth's core. The Mantle is believed to be in a solid state. Although it is in a solid state it also behaves like a liquid, by yielding and bending to long periods of great pressure.

The Crust

The crust of the earth lies outside the Mantle. It is the thinnest layer of the earth. Its thickness is about 16 to 50 kms. The crust is thickest where continents are located and presses deep into the mantle. The crust is thinner underneath the oceans.

The base of the crust is resting on the inner layer called the Mantle. As the mantle is made up of a harder and denser type of rock materials called Olivina, the outer crust which is less dense is not perhaps fully merged with the mantle. The surface of separation between the crust and the mantle is known as the Moho. The word 'Moho' is a contraction of the word Mohorovicic, the name of the scismologist who discovered the existence of this separation by studying the difference in speed of earthquake waves through crust and the mantle. Earthquake waves change in velocity abruptly when they cross the crust and enter the mantle.

An earthquake wave may travel at a speed of 6½ kms. per second when travelling through the crust. It's speed increases suddenly to 8 kms. per second when it enters the mantle of the earth.

The solid substance that make-up the crust, taken together are called the rocks. These rocks are in different forms, shapes and varieties, and are also formed by different processes. Even though the crust is hard, the forces of nature that attack them constantly are capable of changing their form and shape. Different landforms such as mountains, plateaus, plains and valleys are found on the surface of the crust. The temperature increases from the surface of the crust to the interior at the rate of 30°c per kilo metre.

The earth's crust consist of rocks which are an aggregation of particles of various substances. These substances have nearly a constant chemical composition and fairly definite physical characteristics. Some of the physical characteristics of the substances are a crystalline form, a certain hardness, a range of colours and a particular structure and mode of fracturing. Rocks are made up of minerals which are composed of a single chemical element or a combination of two or three elements in chemical union. The crust has all the 92 known chemical elements but many of these are extremely rare. Only eight of the elements exist in abundance, comprising 98 percent of the crust of the earth. They are oxygen (47%), silicon (28%), aluminium (81%), Iron (5%), calcium (4%), soidum, potassium and magnesium (each 2-3%).

The great Austrian Geologist, Suess, formulated a theory that the earth has an arrangement of three shells. Leaving aside the discontinuous sedimentary layer, he called the first layer 'Sial' the name derived from the chemical symbol of silicon and aluminium, which are most abundant in the light rocks of the crust. His second layer was called 'Sima', (Si-silicon and Ma-Magnesium). It contains the comparatively heavy rocks. The third layer, according to him, formed the core of the earth and was composed of the dense heavy material called 'Nife' (Ni-Nickel and Fe-Iron). More recent studies on the careful records and observations of earthquake waves, it is generally agreed that other than the discontinuous sedimentary top layer, the earth could be considered to have an outer layer, an intermediate layer and the central core as explained earlier in this chapter.

QUESTIONS

I. Short answer questions :

1. Define Lithosphere.
2. Divide the Earth's interior structure into three parts.
3. What is Moho ?
4. Explain the term Sial and Sima.
5. What is Nife ?

II. Long answer questions :

1. Give an account of Earth's interior.
2. Explain the salient features of the Earth's Crust.

CHAPTER V

MOVEMENTS OF THE EARTH

The Earth does not stay in one place in the space, nor is it stationary without any movements. On the contrary, it is subjected to different kinds of movements. The fact that earth rotates on its own axis and revolves round the sun reveals two of its major movements, which have already been studied. However, the salient features of the movements are reviewed here briefly.

Due to the rotation of the earth on its own axis, day and night are caused. The distance between every 15° of longitude relates to an hour's difference in time, which is actually the time taken by the earth to rotate 15 meridians. Winds and ocean currents are made to change direction due to the rotation of the earth. So, too, the daily variation in the ebb and flow of the tides.

The Earth takes one year (365¼ days) to revolve around the sun while rotating on its own axis. The axis of the earth which is inclined at 23½° to the vertical of 66½° to the plane of its orbit, around the sun is always in the same direction. This is known as parallelism of the earth's axis, which is mainly responsible for the four seasons to happen. The sun's noon-altitude changes from place to place, and also within a year at the same place, if located outside the tropics. During a year, in certain months, the day time is longer and in other months nights are longer.

Other Movements

The earth is subjected to a number of movements due to the various forces that act on it. Some of them may be termed geologic, some climatic and still others biologic. These forces result in moulding the earth's surface, by forming, adding and altering different kinds of land forms. In general, these forms may be divided into two main groups. One group consists of forces which originate within the earth, and the other forces which originate from without or outside the earth.

Tectonic Forces

The forces of the first group may be due to the changes occurring in the interior of the earth, changes due to chemical combinations, reaction through radio activity, or the shifting of the molten material from one place to another. This group of forces is called Tectonic forces. They are made manifest through process called diastrophism and vulcanism. The process of diastrophism involves the breaking, bending and warping of the earth's crust, as well as the elevations, depressions and displacements that take place at different places. Vulcanism consist of the process that involve the transfer of the molten material from one place to another, either within the earth or at the surface, as an expulsion.

Forces of Gradation

The second group of forces, get their energy mainly from the sun and they are called the forces of gradation. They operate through the agents, such as wind, running water, moving snow and ice and living organisms, working in close relationship with the force of gravity. The ultimate purpose of the forces of gradation is to bring the surface of the land that has different land forms which are existing and still evolving to a uniform low slope. Elevations such as mountains and hills are broken down to rock fragments, soil and sand by the tectonic forces and the depressions get filled up. Weathering, the name given to the various processes of rock breakdown, picking up the rock fragments, and their transportation is collectively termed degradation. Depressions being filled up and the level raised is referred to as aggradation.

Diastrophism

The earth's crust is under constant stress and strain due to the several forces acting within the earth. The disturbances and the dislocation of the earth's crust are in the form of bending, folding, breaking of the crust, resulting in major inequalities on the surface of the earth.

Crustal Fracture

Due to tectonic forces acting on the crust of the earth, crustal fractures have happened at a number of places. The crustal fractures developed in solid rocks result in forming cracks, called

joints, which are numerous near the surface. However, the joints become smaller and with depth and below 20 km. or so, it is believed that they do not exist. The joints enable the ground water to circulate more freely within the rocks and help the agents of gradation to work more rapidly.

Under severe stresses rocks not only break but also move along the plane of fracture and are displaced. Such displacements are called faults. The displacements can be in the vertical or horizontal direction. When the rocks on one side of the fault are elevated, as different from the other side, the cliff that is produced is called a 'fault scarp'. The displacement in the horizontal direction results in breaking and off-setting of roads, railway lines and boundary lines.

In the case of parallel faults, the segments of earth between them may be uplifted or dropped down due to stress. The block-like uplifted land is called a 'horst' or a 'block mountain'. A mountain like landmass may also be formed by the subsidence of land outside the faults. Basin Ranges of U.S.A., Vosges, and Black Forest mountain of Europe belong to this category.

The depression of land formed between two parallel faults is called a 'rift valley' or 'garben'. Vast trenches of this type are sometimes filled with water, such as Red Sea, Dead Sea, Lakes Tanganyika, Nyasa, etc.

Crustal Bending

In certain earth deformations, the stress has been applied to rocks so slowly that, instead of fracturing, they bend or even fold. The bends and folds will be either small or of mountainous proportions and either simple or complicated. The crust or the arch of one of these simple folds is called 'anticline' and the troughs or valleys, the Rockies and the various Alpine Chains are all fold mountains.

Crustal Warping

Such as the folding of the earth's crust in some places, parts of it yield to stress by warping, which is merely a bending or flexing without any folding of the crustal material. This type of bending

affects vast areas and is continuously in progress but it takes thousands of years to notice marked results. Because of warping, large areas of low plains have been lowered very slowly by a few metres and thus added to the shallow sea bottoms. By the very same process broad areas of the shallow sea bottoms have been

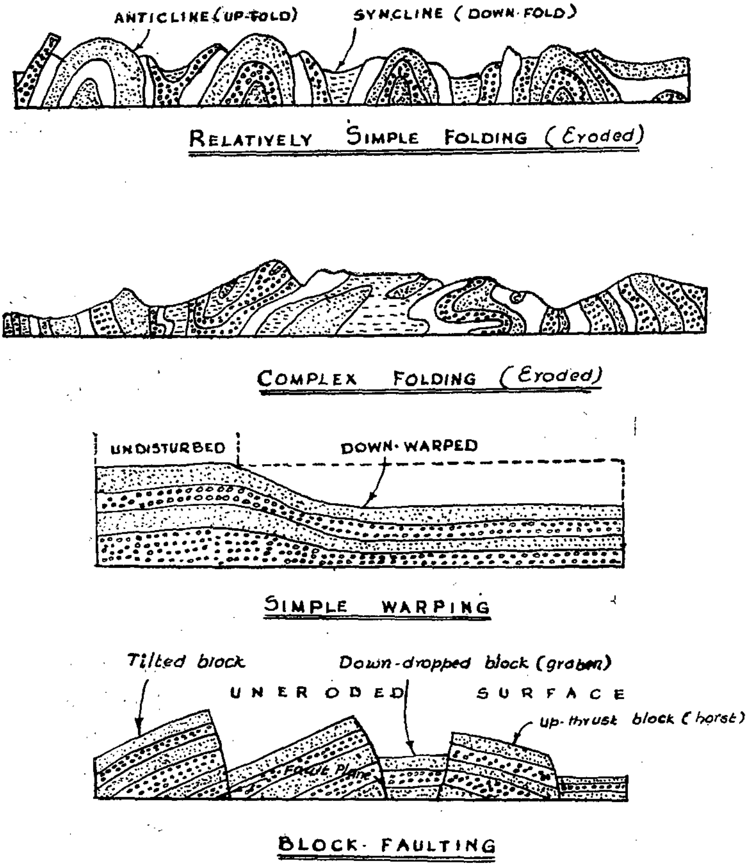

FIG. 5.1 Folding and Faults

slowly raised and added to the areas of the continent. In North America, the State of Florida is a relatively recent addition to that continent in terms of geological time. The fossil remains of sea animals in sedimentary rocks that are found in the interior of conti-

nents indicate that some of these areas were uplifted from the sea far back in Geological History and some others in more recent times. For the uplifting of the sea beds and lowering of the land surface, the eroding action of the oceans is one of the major causes. In 1287, in England, the town of Vinjelliah, in the boundary of Essex-Kent was submerged in the sea due to a big cyclone. The ancient and famous trade centre of Pumpuhar in Tamil Nadu, was completely washed away by the sea. Of recent happening is the submergence of Dhanushkodi, a coastal town near Rameswaram, on the gulf of Mannar. However, the town of Andria, which used to be on the shore of the Adriatic Sea, is now situated about 20 km. interior. Similarly the mouth of river Ganges has advanced into the Bay of Bengal. The examples mentioned above indicate that the action of tectonic forces, as well as the work of rivers in transporting and depositing the alluvial soil and the action of the seas are the major causes for elevating submerged land above sea-level and in submerging land. Normally, the sea surface provides the ready reference level for signifying the uplifting and the lowering movements affecting the earth's crust. (Fig. 5.1).

Earthquakes

Some of the changes that take place on the crust of the earth are sudden and quick. Others indicate silent process that takes place during thousands of years. Sudden changes, however, are mainly due to earthquake. In Turkey and Iran, several towns have been destroyed due to frequent earthquakes. Sometimes large gaps which are a permanent change in the surface level, are due to earthquake that occurred in New Zealand in 1855 resulted in an lift of the surface by 3 metres and the San Francisco earthquake of 1906 observed displacement of 7 metres which was indicated by the horizontal off-set of a road.

Vulcanism

The term vulcanism includes all movements of the molten rock (which is called magma) in the interior of the earth and the phenomena which are associated with these movements. More information is given in the section separately dealing with this topic.

QUESTIONS

I. Short answer questions :

1. What do you understand by the term Tectonic forces?
2. Define fault.
3. What is a fold?
4. What is Vulcanism?
5. Define Diastrophism.

II. Long answer questions :

1. Explain the various movements of the Earth.
2. Describe the Crustal fractures.

CHAPTER VI

EARTHQUAKES

An earthquake is a shaking of the earth's crust. The vibrations, which are started when an earthquake takes place, travel in all directions in the form of waves. The terror and destruction that earthquakes have brought to man, have resulted in a careful study of the regions most affected by earth tremors, and in the development of methods for detecting and predicting them. This scientific study of earthquakes is called seismology.

Earthquakes are caused when rock masses move suddenly along the line of a fracture or a fault in the crust of the earth. These fractures and faults are produced when the rocks of the earth's crust move in a large scale, due to tectonic forces acting within the earth. The rock masses on either side of such fractures might slip suddenly either downward or upward resulting in disastrous earthquakes.

Sometimes earthquakes take place as a result of volcanic explosions. Such earthquakes are common in regions of intensive volcanic activity. Volcanic eruptions are often preceded or accompanied by earthquakes. In Japan, which is a region of intensive volcanic activity, earthquakes occur almost every day, throughout the year. However, most of the earthquakes are of small intensity, more of earth tremors. The majority of the most destructive earthquakes are those which are caused by the movements of huge masses of rocks along faults, which may be new faults or old ones.

Earthquakes taking place on an ocean bed cause huge sea waves, which rise to greater and greater heights, as they approach the coastline. Such a wave is called Tsunami On a single occasion it has been known to cause deaths by drowning thousands of peoples. Sometimes, Tsunamis are as high as 30 metre but last only for a short duration. The sea shores of Japan and the western coasts of the Americas are frequented by Tsunamis, causing disastrous effects.

Earthquakes originate beneath the surface of the earth. The place directly above the point of origin of the earthquake is called the epicentre. As the vibrations spread outwards from the place of the origin of the earthquake, their intensity diminishes. Far away from the centre of origin, very little damage occurs. Nearer the centre the shock may be so great that not even the most solidly constructed buildings remain intact. At the epicentre itself the intensity of shaking is at its greatest. But because the movement is up and down, destruction of buildings is not at its maximum.

Earthquake waves travel along the surface of the earth. They move in circles like the waves set in motion on the surface of a pond by throwing a stone. Other waves travel through the interior of the earth. When the waves reach the core of the earth, they are deflected away from the centre of the earth.

In many of the important cities of the world very delicate instruments are kept to record the earthquakes. Most of them can record the earthquakes that occur at a distance of two or three thousand kilometres away. The measuring scale of earthquakes, most commonly quoted in news reports is the Richter Scale. Zero is the smallest recorded earthquake and 8–9 the largest. A seismograph is an instrument for recording earthquake shocks. The recording is by a pen tracing on a revolving drum or on a moving film. Actually, a properly equipped seismological observatory has three different seismographs. Two of them record the horizontal components of the earth's vibrations, one in the north-south direction and the other in the east-west line. The third records the vertical component.

In the violent San Francisco earthquake of 1906, the magnitude of the earthquake was 8.3. and the damage caused was tremendous. In 1949, a violent earthquake devasted several thousand square kilometres of territory in Ecuador in South America, causing landslides that burried whole villages, damaming up a river to form a lake, destroying nearly every building in some cities and causing several thousand deaths. Fortunately, some of the greatest recorded earthquakes, such as the great 1950 earthquake in Assam, have occurred in sparsely settled areas.

In India, the plains of Ganga and Brahmaputra are frequented by earthquakes. In 1934 in Bihar and in 1897 and 1950 in Assam

violent earthquakes have caused great damage. The Quetta earthquake of 1934 destroyed the town and resulted in several thousand deaths. The disastrous effect of the earthquakes is due chiefly to the suddenness of the vibrations.

In big cities, such as London, Paris and Berlin, severe earthquakes do not occur. But in Tokyo, Yokohama, Vulparaiso, Peking earthquakes occur frequently.

As in the case of volcanic activity, earthquakes also occur in certain definite regions of the earth. Approximately 68 per cent of the earthquakes occur round the Pacific Ocean regions. In Andes and Rocky mountain ranges, Alutian and New Zealand Islands and east Asian Island groups, earthquakes are common features. Next to these in the Mediterranean region earthquakes are felt frequently. Every now and then, earthquakes occur in the West Indies Islands, Alps mountains and the mountain ranges from Turkey to the East Indies islands. The greater part of the Deccan Plateau is, however, free from earthquakes.

QUESTIONS

I. Short answer questions :

1. Define earthquake.
2. What is a seismograph?
3. What is a Epicentre?

II. Long answer question :

Explain the salient features of earthquake.

CHAPTER VII

VOLCANISM

Magma

A sufficient reduction in pressure or a sufficient increase in temperature will result in the melting of the hot rocks, 50-800 kms. below the surface of the earth. The molten rock inside the earth is called **magma** and the phenomena connected with the magma and its movement are called **volcanism**.

The molten rock moves in the direction of the greatest pressure decrease and therefore follows a general trend upward. The hot fluid mass flows through any available cracks and into cavities between rock layers and solidifies beneath the surface. Sometimes, moving upwards, it reaches the surface and it pours out either through a volcanic opening or through a fissure in the surface rocks. Sometimes the molten rock material gets solidified deep down beneath the surface. The solidified magma is termed as igneous rocks (igners-fire) and has different names according to the depth and manner in which they have solidified. Igneous rocks formed by solidification below the earth surface are called intrusive igneous rocks and those formed on the surface are called extrusive. Some forms of intrusive igneous rocks are batholeths, laccoliths, sill and dyke.

Batholith, a dome-shaped mass of rock formed by the intrusion of magma often consists of granite. It is usually much larger than a laccolith, often extending over hundreds of square miles. They form the sub-structure to mountain ranges and appear to continue downwards to enormous depths. Laccolith is caused by the intrusion of magma from below into the crust of the lithosphere without reaching the surface, the surface being arched up over the intrusion. When the magma forces its way between two layers of rocks and solidifies, the formation is called **sill**. Its thickness may be a few inches or several hundred feet, but its horizontal extent is usually great in comparison to its thickness. A sill often

gives rise to Dykes which are veltical or highly inclined sheets of igneous rock formed below the surface of the earth, when the magma forces its way upward through a cleft and solidifies.

In the interior of the earth, the cooling of the magma takes place slowly, thus allowing time for the crystallization of the different minerals. A rock which has solidified deep down in the interior of the earth is usually completely crystalline. Such igneous crystalline rocks are called **plutonic** rocks. Granite is a good example. Molten rock materials which cooled more rapidly are not fully crystalline and are glassy in texture.

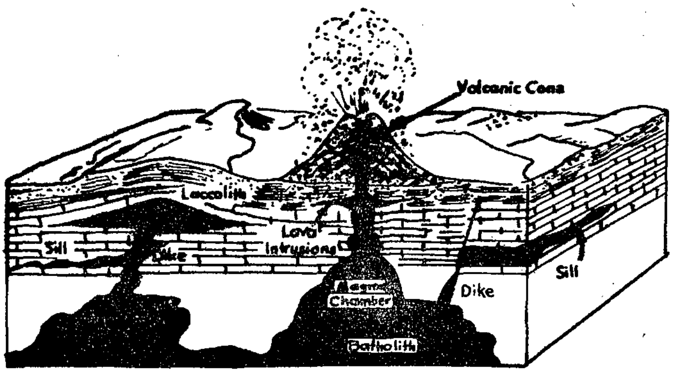

FIG. 7.1 Volcanic Eruptions

Volcanic Activities

Volcanoes are formed when the molten rock materials in the interior parts of the earth escape to the surface of the earth. For this, in the first place, there must be a passage of escape, leading from the surface of the earth right up to the molten part in the interior. Such passages may be more or less round holes or long fissures. Both kinds of passages have produced volcanic eruptions in the world.

A volcano is usually a conical hill. At the top of the cone there is a circular hollow which is called the crater of the volcano. In the middle of the crater, there is usually a round hole which serves as the passage for the escape of molten rock material which

is poured out is called Lava. A volcanic eruption does not always consist of quiet pouring out of molten rock materials alone but often there are terrific explosions. Large and small broken pieces of solid rocks are thrown out to a great height. Huge quantities of steam and various gases come out of the crater. The large pieces of the solid rock materials which are thrown out, are called 'Breccia' and the smaller ones are named Cinder and Ash. The very fire materials are the volcanic dust. In a typical explosive, a giant cloud of steam and dust billows skyward, preceded by great volumes of superheated steam and other suffocating or poisonous gases. The clouds drift with the wind and disperse over large areas. The steam and the ascending air currents condense and result in torrents of rain accompanied by lightning and thunder. After the explosive phenomenon is over, the eruption is likely to continue more quietly. The cone-shaped volcanic hill grows round the crater by the accumulation of the solid and liquid material thrown out from the crater during the explosive period as well as later.

There are in the world, many old volcanoes in which eruptions do not occur. These are called dead volcanoes or extinct volcanoes. Some volcanoes are called dormant volcanoes. A dormant volcano is one which has not erupted for several years but might erupt any day. An active volcano is one in which eruption takes place now.

When the rock materials thrown out from volcanoes decompose, they usually form very fertile soil. A large area in the North Western part of the Deccan Plateau is covered by black, clayey soil. This black soil owes it origin to volcanic activities—an immense quantity of molten basaltic rock material poured out of long fissures over this region. In course of time, the basaltic soil became decomposed into the black soil of the Deccan Plateau.

Regions of Volcanic Activity

Volcanoes are not located in a haphazard manner in the world. There are many volcanoes which are active around the Pacific ocean. Japan, Phillippines and the East Indies have many active volcanoes. Along the Western side of South America and North America, both in the Andian mountain chain and in the Cordillera

belt, there are many active volcanoes. There are no volcanoes in the Himalayan mountains. In the Mediterranean region there are a few great volcanoes such as the Vesuvius in Italy and Mt. Etna in the Island of Sicily.

Geologists point out that volcanism has existed ever since the earth took shape and that the rise of magma has occurred several times in different parts of the earth. The present active volcanoes, which number about four hundred are mostly of recent origin. The distribution of the active volcanoes follows remarkably the earthquake zones and the zone of the most recent mountain building process. One zone is along the margins of the Pacific Ocean basin, forming the famous 'belt of Pacific', from the tip of South America to Alaska, from Alaska to Japan and from Japan to Phillippines. The Mediterranean Zone extends east and west from Central America through the West Indies to the Azores, the Canary Islands and the Mediterranean and from the Mediterranean through Turkey, Iran and Iraq to the East Indies, where it crosses the Pacific belt. The distribution of Volcanoes and the young mountains along the same zone, point to the relationship between the two. Since the young mountains are produced by extensive folding and faulting (fracturing) the folded zones develop fissures through the crust of the earth, through which magma rises causing volcanic eruptions and intrusions and extrusions. Therefore notable volcanic activity appears to be associated with regions of principal diastrophism.

QUESTIONS

I. Short answer questions:

1. What is Batholatith?
2. What is Breccia?
3. Define the term Dyke.

II. Long answer question:

Describe the various volcanic activities.

CHAPTER VIII

ATMOSPHERE

The Composition and Structure of the Atmosphere

Our solid earth is surrounded by an ocean of air known as Atmosphere. The existence of life on this planet (Earth) owes very much to the presence of its atmosphere. Of all the elements of the natural environment, man and his activities are mostly influenced by the characteristics of the atmosphere and the changes that take place in the atmosphere.

The atmosphere extends at least up to 10,000 km. and is pulled towards the earth surface by the gravitational force. Heavy, dense gases in the air occur in the lowest layers while light gases are gradually found in the higher layers. Due to the gravitation force, nearly half of the air lies within the altitude of 6,000 mt. and another one fourth lies between 6,000 and 12,000 mt. from the surface of the earth.

Composition

The atmosphere is a mechanical mixture of numerous gases. Of these only four gases namely, nitrogen, oxygen, orgon and carbon di oxide make up over 99% by volume below 99 km. Nitrogen alone constitutes about 78% of its total volume. Oxygen, the most vital life sustaining gas, accounts for 21%. The remaining one percent is shared by the other gases. Though carbon di oxide constitutes an insignificant amount (0 03%) it is indispensable to plant life as it aids photosynthesis.

In addition to these gases, water vapour and dust particles are also present in the lower layers of the atmosphere. Except for the water vapour present, the composition is remarkably homogeneous at least up to 50 km The amount of water vapour varies

from 0·2% over the deserts, to 4% over the humid tropics. But this little variation results in the major climatic changes since :

(1) it is the single source of all forms of condensation and precipitation.

(2) it is the absorber of solar as well as terrestrial energy.

(3) it acts as a store-house of energy. It stores heat energy in the form of latent heat. It also affects the rate of cooling of the human body and thus influences the sensible temperature.

In the same way the dust particles contained in the atmosphere, have some important climatic consequences. Smoke emitted into the air from the chimneys, automobiles, etc. are the main sources of dust. Dust particles influence weather conditions in the following ways :

(1) They reflect and scatter the solar radiation.

(2) Dust particles act as a hygroscopic nucleii on which condensation of water vapour begins.

The Structure

The atmosphere is stratified into 4 recognised layers with varying densities, Troposphere, Stratosphere, Ionosphere and Exosphere. The density is highest near the earth's surface and decreases upwards.

Troposphere, the lowest gaseous layer, extends approximately up to a height of about 8 km. near the poles and about 18 km. at the equator. It contains more than two-thirds of the air in the atmosphere. Most of the weather changes occur within this layer. In this layer atmospheric temperature decreases at the rate of 1°C for every 165 mt. of ascent.

Stratosphere follows troposphere and extends up to a height of about 80 km. At the equator it is about 62 km. thick and 72 km. thick at the poles. This layer is characterised by the negative lapse rate and absence of change in weather phenomena. At an elevation between 25-35 km. there is a distinct ozone layer. This layer absorbs all the ultra violet rays from the sun and prevents the earth from getting overheated.

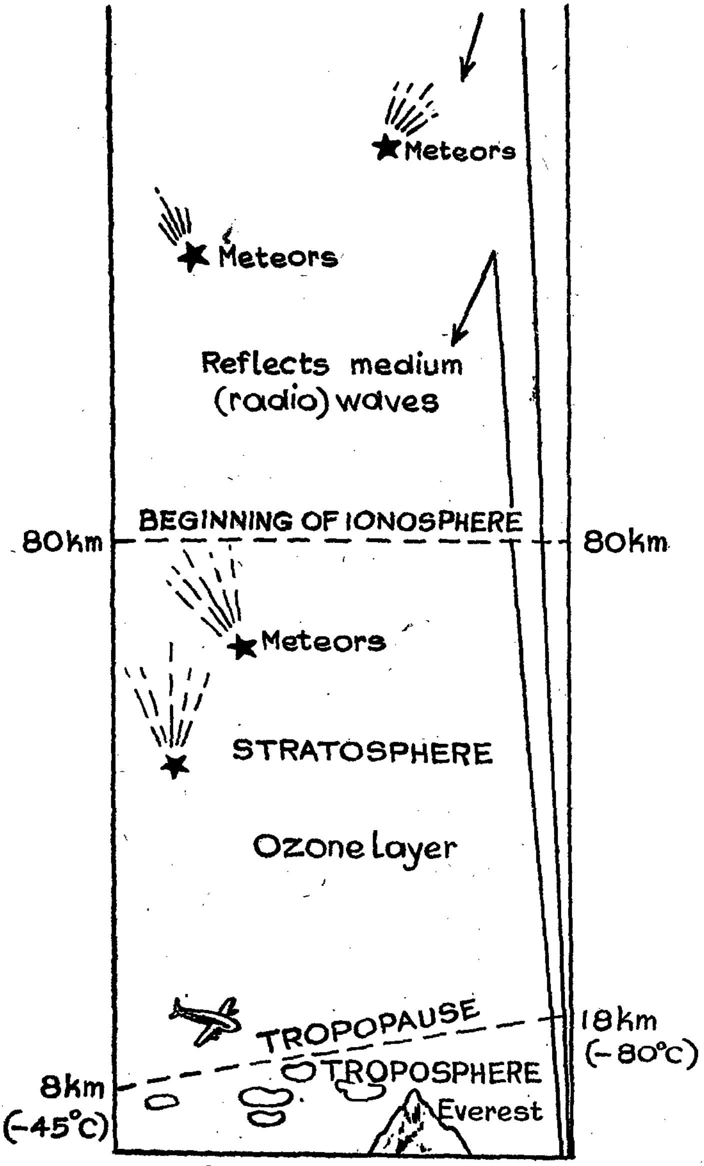

FIG. 8.1 Important Layers of the Atmosphere

The transitional zone which distinguishes troposphere from stratosphere is known as 'tropopause'. The layer above stratosphere is known as ionosphere. It extends to a height of 1,050 km. and is about 970 km. thick. This layer contains layers of ionized air which reflect the radio waves back to the surface.

The outer most layer of the atmosphere is termed as Exosphere which extends up to a height of 9,600 km. The air at this altitude is so thin and rarely its atoms collide with each other. This is the transitional zone between the earth atmosphere and space. It is inaccessible and hence very little is known about its structure.

QUESTIONS

I. Short answer questions:

1. What are the significances of Water Vapour in the atmosphere ?
2. What is the importance of the dust particles in the atmosphere ?
3. What are the different layers of atmosphere ?
4. What are the characteristic features of statosphere ?

II. Long answer question :

Describe the structure of the atmosphere and the different characteristic of each of its layers.

CHAPTER IX

TEMPERATURE

The conditions of weather at any place and time depend upon the inter-relationship between the following three basic elements :

(1) Temperature (2) Pressure and winds and (3) Moisture.

Unless we study the elements individually, it would be impossible to understand the complexity of this inter-relationship which determines the weather.

Solar Radiation

The sun is the primary source of heat for the earth. The heat conducted from the interior of the earth and the energy radiated from the other celestial bodies form a negligible amount. The sun radiates energy in the form of heat. This is known as solar radiation. Owing to its small size and great distance from the sun the earth receives only one in two billionth part of the solar energy. But the existence of life on the earth's surface owes very much to this fraction of solar radiation.

The incoming solar radiation received by the earth is known as **insolation**. This insolation is the ultimate cause for all the changes that take place in the atmosphere. Out of the total insolation received by the earth 35% of the energy is radiated back to the space as soon as it reaches its outer limit and only the remaining 65% of the energy reaches the earth's surface.

The Process of Heating and Cooling of the Atmosphere

The sun is no doubt the ultimate source of energy for heating the atmosphere. But only an insignificant portion of the insolation is directly absorbed by the atmosphere. Most of its energy is indirectly received through the earth's surface. The processes by which the atmosphere is heated up are conduction, convection and terrestrial radiation.

CONDUCTION

Conduction is the process of transfer of heat energy when two bodies of unequal temperatures come into contact with each other. The surface of the earth absorbs the insolation and is heated up. This heat is transferred by conducting to the layers of the air immediately above the earth's surface and from that layer to the successive layers farther above. In the same way when the surface is cooler than the overlying air the heat transfer is reversed. Since it is a slow process, conduction accounts only for a minor portion of the heating and cooling changes in atmosphere.

CONVECTION

When the air in the lower layer gets heated up it expands and becomes lighter. The warm, light air moves up and it is replaced by relatively cooler and denser air from above. This causes a continuous cyclic circulation of air in transferring heat from the lower to the upper part of the atmosphere. This process of transfer of heat is known as convection.

TERRESTRIAL RADIATION

The Sun radiates its energy in the form of short waves. Being a non-absorber of short wave radiation, the atmosphere acts as a transparent medium. The earth's surface which is heated up by the solar radiation, radiates its energy in the form of long wave radiation. This is also known as terrestrial radiation. The atmosphere absorbs the large share of its energy from the terrestrial radiation.

Measurement of Heat

The degree of heat of any body is referred to its temperature which is measured by a thermometer. The temperature is usually expressed in degrees either in Celcius or Fahrenheit scales.

Distribution of Temperature

The distribution of temperature varies both horizontally and vertically.

Horizontal Distribution of Temperature

Even if we presume that the earth's surface is uniformly plain, temperature would change from place to place. The horizontal distribution of temperature depends upon number of factors like the inclination of the earth's axis, duration of sunlight, the nature of the surface, prevailing winds and ocean currents.

Inclination of the Earth

The sun's rays are parallel to each other since they come from an indefinite distance. Owing to the curvature of the earth's surface they strike the surface at different angles. Near the equator, the sun's rays are almost vertical and are concentrated in the smallest possible area. As a result the surface is intensively heated whereas in the high latitudes the sun's rays are oblique.

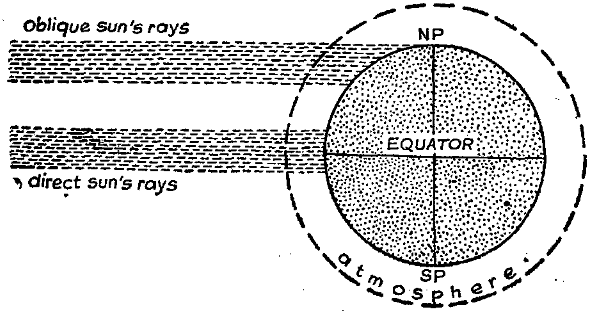

FIG. 9.1 Vertical and Oblique Rays of the Sun

Oblique rays fall over a large area and hence only a little heat is available at a particular point. Hence the temperature progressively decreases from the equator towards the poles.

Duration of Sunlight

Latitude and the season of a given place determine the length of time, when the sun is above the horizon. At the equator the average day time is longer than that of the poles. In the same way at all the localities the length of the day time varies with the season. For example, at latitude 45° N the sun is above the horizon for 15 hours and 37 minutes during the summer solstice and only 8 hours and 46 minutes during the winter solstice.

Nature of the Surface

Owing to the contrasting characteristics, heating and cooling of land and water surfaces vary considerably. The land surface is heated and cooled more rapidly than that of the water surface. During the summer season the land gets heated up quickly and the air over the land is warmer than that of the ocean surface whereas during the winter the air over the water surface is warmer than that of the land surface.

There are several other factors such as relief, vegetation, ice cover, prevailing winds and oceans currents which also affect the distribution of temperature to some extent.

The horizontal distribution of temperature is usually shown by isotherms. Isotherms (iso means equal; therm means temperature) are imaginary lines joining places having equal temperature. Due to variation in the amount of insolation received by the earth surface, the mean annual isothermal value gradually decreases away from the equator.

[A mean annual isotherm joins places having the same mean temperature reduced to sea level (in order to eliminate the influence of altitude) for the whole year.]

The apparent seasonal migration of the sun between the tropics also influences the horizontal distribution of temperature. This is clearly seen from the January and July mean isotherms which bring out the seasonal extremes of temperature.

During the month of July, the sun is found north of the equator. During this period, the northern hemisphere experiences its summer while the southern hemisphere experiences its winter. In the northern hemisphere the land masses are heated quickly and comparatively warmer than that of the water bodies. Therefore the isotherms bend poleward while crossing the land and bend equatorward while crossing the sea.

During the same period in the southern hemisphere the oceans are warmer than that of the land masses. So the isotherms bend towards equator while crossing the land and poleward when crossing the oceans.

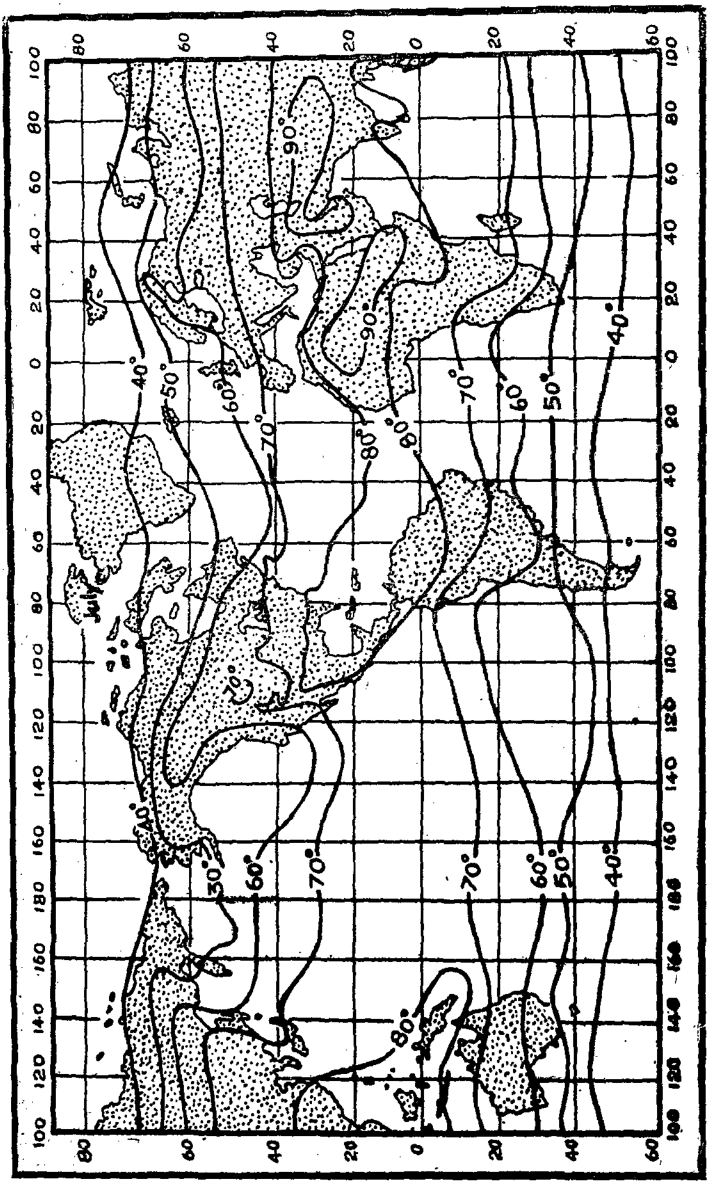

FIG. 9.2 July Isotherms

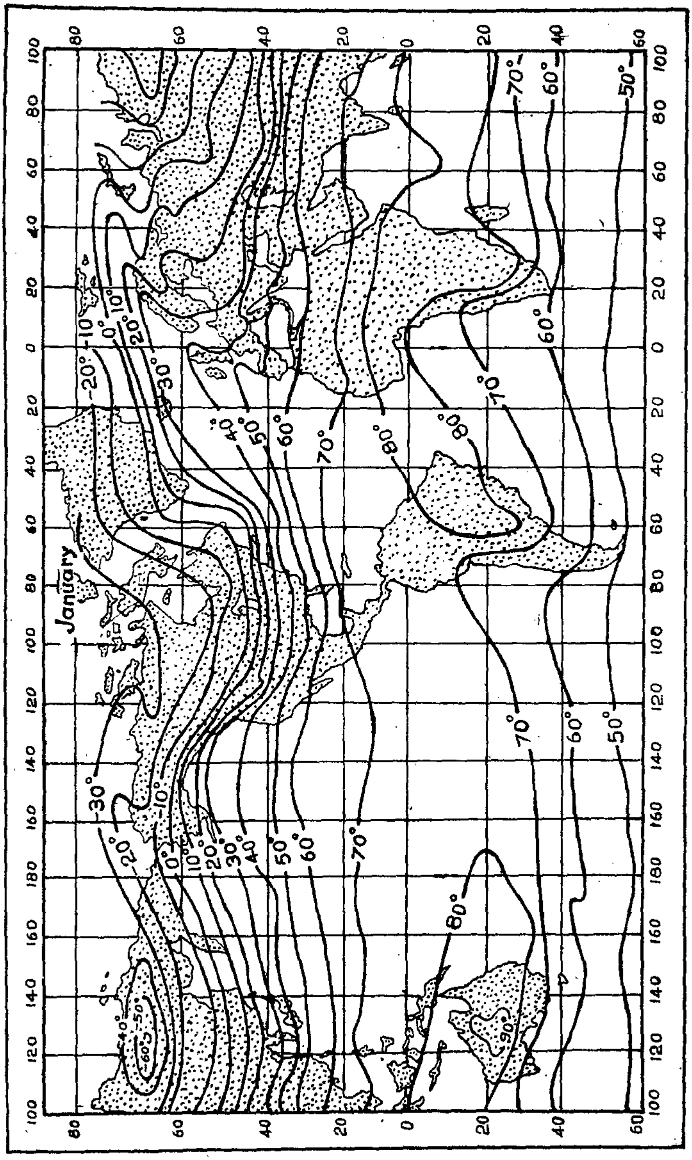

FIG. 9.3 January Isotherms

In the month of January, the sun shifts its position and is overhead on the Tropic of Capricorn and it becomes winter in the northern hemisphere and summer in the southern hemisphere. The reverse conditions to that of July are found in the bend of isotherms. The seasonal variation in the shifting of isotherms are clearly pronounced in the northern hemisphere where land predominates with intervening water bodies while in the southern half, seasonal variations are conspicuous because of the absence of large land masses.

Ocean currents exert their influence on the temperature of the bordering coastal areas. Warm currents raise the temperature and cold currents decrease the temperature of the coastal areas. It is obvious from the isothermal maps that the lands bordering the western part of the Atlantic are warmer than their counterparts in the eastern side at the same latitude mainly due to the presence of warm currents.

Vertical Distribution of Temperature

As the temperature decreases from lower latitude to higher latitudes, it also decreases from lower altitude to higher altitudes. The permanent ice caps of the tropical and sub-tropical regions are the standing examples to understand the vertical distribution of temperature.

Atmosphere derives its heat mainly from the earth's surface below. The lower layer of the atmosphere which is in contact with the earth is warmer than that of the higher altitudes. Hence if we go higher and higher the temperature gradually decreases. Under normal conditions the rate of decrease in temperature with the increasing altitude is approximately 1°C for every 165 mt. This is known as **normal lapse rate.**

Inversion of Temperature

Sometimes we find temperatures increasing instead of decreasing with an increase in altitude. This is known as inversion of temperature. This usually happens in the middle latitudes during the cold, dry and clear winter nights. During the nights, the surface loses its heat due to rapid radiation. So the layers overlying the surface are cooler than the layers in the higher altitudes.

Ideal conditions for the formation of inversion of temperature are :

(1) Long winter nights permitting rapid radiation.

(2) Clear sky without clouds since the presence of clouds would result in the reflection of radiated energy back to the surface.

(3) Dry air with slight wind movements.

QUESTIONS

I. Short answer questions :

1. What are the elements of weather?
2. What is solar radiation?
3. Define 'isolation'.
4. What are the processes through which heating and cooling of the atmosphere take place?
5. Define 'Isotherm'.
6. What is meant by 'Normal Lapse Rate'?
7. What do you understand by 'inversions of temperatures'?

II. Long answer question :

What are the factors that affect the horizontal destruction of temperature? How do they affect?

CHAPTER X

PRESSURE AND WINDS

Even though we are not aware of the weight of the air column standing on us, it exerts a considerable pressure. Like any other matter on the earth, air is also attracted towards the earth due to its gravitational force. Hence it exerts its weight as pressure on the earth's surface. To a large extent pressure depends on temperature, as a result it controls winds and affects rainfall. Hence the pressure of any locality provides a clue to forecast the weather.

Measurement

The atmospheric pressure may be defined as the weight of the air column resting on the earth's surface. It is measured with the help of an instrument called barometer. It is usually expressed in millibars. A millibar is a force equal to 1,000 dynes per square centimeter and a dyne is a unit of force approximately equal to the weight of a milligram.

If the mercury column in the barometer stands to a height of 75 cm., the atmospheric pressure is equal to the weight exerted by a column of mercury 75 cm. in height. Thus the atmospheric pressure can easily be expressed in centimeters and millimeters. Since pressure is a force, it is expressed in millibars. One millimetre of pressure is equal to 1.333 millibars. Under normal conditions, the atmospheric pressure at sea level is 1,000 millibars (76 cm.).

Vertical Distribution of Pressure

Near the surface of the earth the entire weight of the air column exerts a pressure higher than the layers above. For example, at the sea level the pressure is higher than that of a hill top. Therefore pressure decreases with increasing altitude. Normally it decreases at the rate of 34 m for every 300 m of ascent. But this normal rate of decreases is held correct only in

the lower layers. Since the density of the lower layers of the atmosphere is higher than the layers at the higher levels, the rate of decrease increases rapidly with the increase in altitudes.

Horizontal Distribution of Pressure

The atmospheric pressure varies from place to place on the surface of the earth. There are a number of factors which effect the horizontal distribution of pressure. Temperature, season and altitude of a particular location largely determine the pressure of that location.

Horizontal distribution of pressure is represented by **isobars.** Isobars like *isotherms are also isolines.* Isobars are lines joining places having equal pressure. They are shown on the map as reduced to the sea level in order to eliminate the influence of altitude.

If the rate of change of pressure is rapid, the isobars will be spaced closely. If the *isobars are sparse it is inferred* that the rate of change of pressure is not rapid. The rate of change of pressure is termed as pressure gradient.

If the pressure decreases towards a centre, it is named as low pressure and if it increases it is known as high pressure. The terms high pressure and low pressure are only relative terms. The low pressure areas are often termed as 'lows', or 'troughs' and the high pressure areas are called as 'highs' or 'ridges'.

Pressure Belts

Temperature is an important element affecting the horizontal distribution of pressure. Pressure is often termed as the resultant effect of temperature. If the temperature alone is taken as a criterion for the distribution of pressure, then the pressure would progressively increase towards the poles. The actual distribution differs from the pattern. The presence of a low pressure in the equatorial region and high pressure in the polar regions help to explain the unequal heating of the earth's atmosphere. But this fails to explain the presence of high pressures *in the sub-tropics* i.e., about 35°N and 30°S and low pressures at about 60° north and south.

The heating of the atmosphere is the highest near the equator. Hence a narrow and continuous belt of low pressure is formed. This equatorial low pressure lies between 10°N and 10°S. The entire belt is also known as 'doldrums.'

As a consequence of intensive heating, the air rises upwards in the equatorial region. The ascending air currents become cooled and the further upward movement is restricted. This causes a high pressure to be built up at the higher levels (about 3,750 m).

At this height the pressure is higher than that of the polar regions. Hence the upper air tends to move towards the poles.

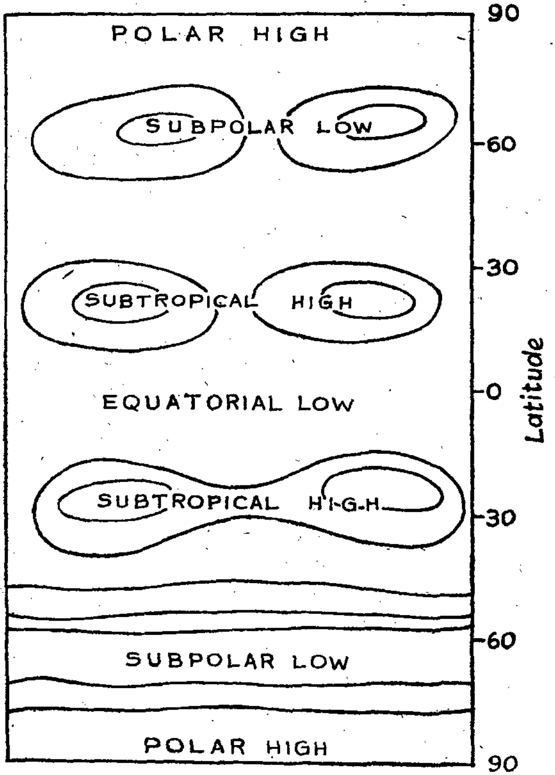

FIG. 10.1 Idealized Arrangement of Zonal Pressure Belts

Due to the rotation of the earth, the movement of the upper air is deflected mòre and more eastwards and become an upper westerly whirl. As a result the movement towards the poles is restricted and piled up in the sub-tropics. This results in the formation of a high pressure belt known as Sub-tropical High Pressure in each hemisphere. In between the sub-tropical and polar high pressures the pressure tends to decrease to form low pressure regions called sub-polar low pressure belts. These are also known as north and south temperate lows.

The generalised picture of pressure belts are shown in Fig.10.1 The pressure belts are more conspicuous in the southern hemisphere than in the northern hemisphere. This is mainly due to the absence of large land masses in the southern hemisphere.

Seasonal Variation in Pressure

The pressure belts shift their position in response to the migration of the sun. The distribution of continent sand oceans also exert a marked influence on the seasonal variation in pressure distribution.

In the northern summer, the equatorial low pressure follows the sun and is located north of the equator. In fact all the pressure belts experience a similar latitudinal shift. Land masses become hotter than the oceans in the northern hemisphere. As a result, low pressures develop over the continents. The sub-tropical high pressure belt is broken over the land and confines itself over the oceans. The whole of the Asian continent comes under the influence of the low pressure interrupting the sub-tropical high pressure system.

In the northern hemisphere the sub-tropical high pressure is well developed during the northern summer.

During the southern summer the equatorial low pressure is located south of the equator. The cells of sub-tropical high pressure are well developed over the oceans. It is more conspicuous in the northern hemisphere than in the southern hemisphere. The whole of Asia and North America come under the influence of high pressure. The cells of sub-polar low are located over the oceans in the northern hemisphere.

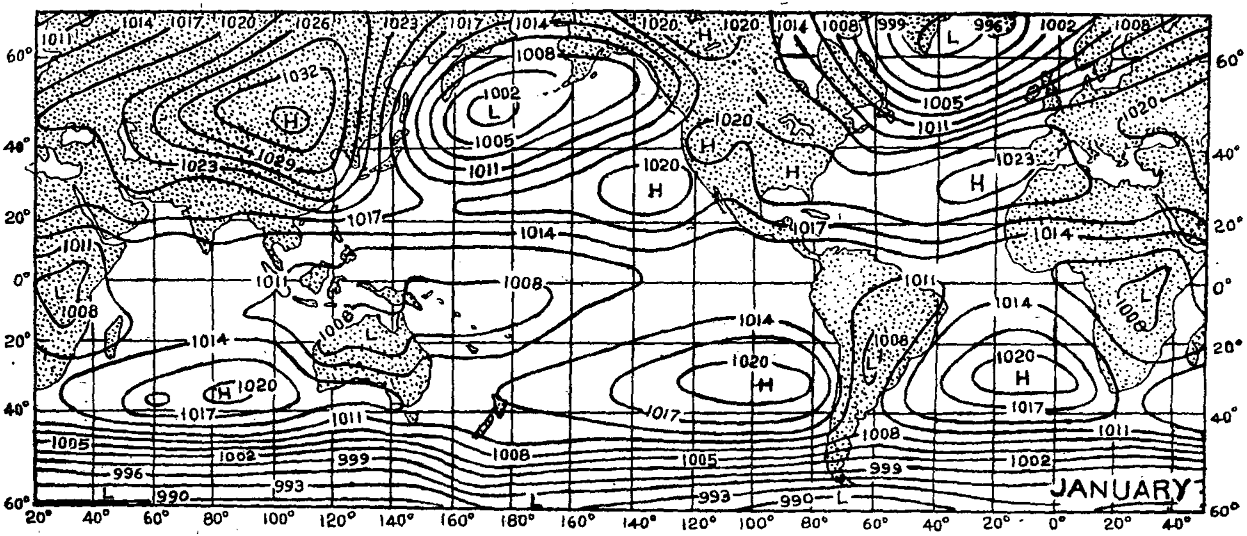

FIG. 10.2 Distribution of Mean Sea Level Pressure – January

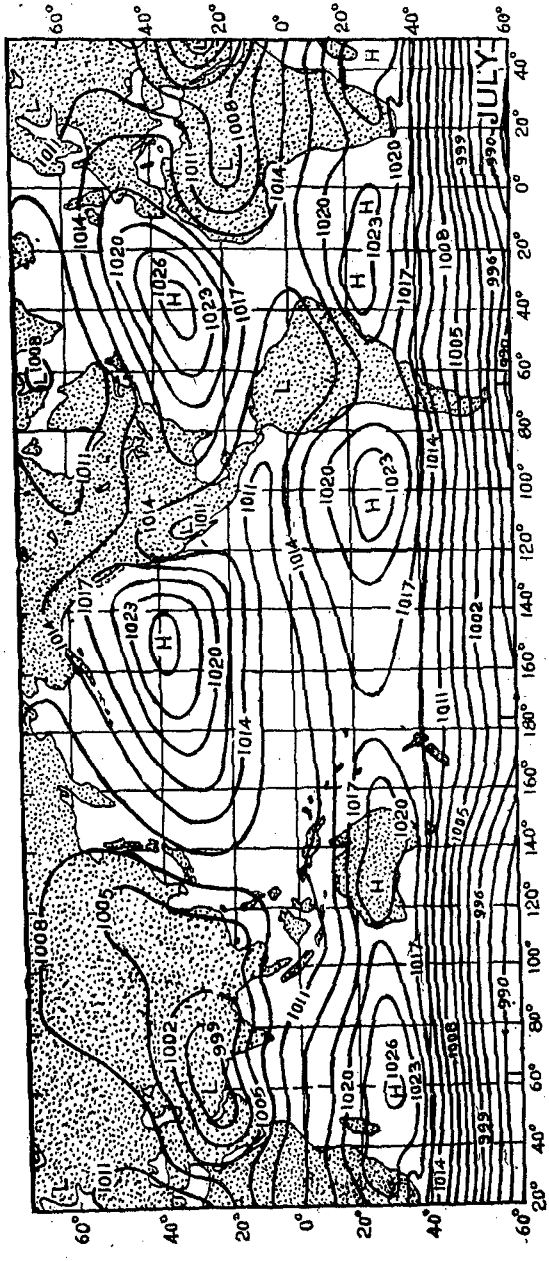

FIG. 10.3 Distribution of Mean Sea Level Pressure — July

Winds and Atmospheric Circulation

Horizontal movement of air is called **wind**. Winds are caused by the horizontal differences in air pressure. It represents the nature's way to adjust pressure in equalities. If there is a horizontal pressure difference, there exists a pressure gradient. The pressure gradient makes the air to move from the high to the low pressure. A pressure gradient has both direction and magnitude. If the pressure gradient is steep the wind will blow at a greater speed. If the pressure gradient is not steep then the wind speed will be much lower. Velocity of wind is mostly determined by the slope of the pressure gradient although air density, latitude and friction are also involved.

Winds are always named by the direction from which they are blowing. Thus winds from the west are called Westerlies.

Wind Belts

From the generalised pressure belts we can also expect generalised wind belts. Winds tend to move towards the equatorial low from the sub-tropical high pressure in both the hemispheres. Similarly the winds from the sub-tropical high and the Polar high tend to move towards the sub-polar low pressures (Fig. 10.4).

According to the Ferrel's law, 'All moving bodies are deflected to the right in the northern hemisphere and to the left in the southern hemisphere.' Due to the deflection force caused by the earth's rotation, the winds blowing in the southern hemisphere are deflected towards its left and the winds moving in the northern hemisphere are deflected towards its right. But for the deflective force of the earth's rotation the direction of the wind movement would be either from south or north and almost perpendicular to the isobars.

Trade Winds

The winds moving from the sub-tropical Highs towards the equatorial low pressure are deflected towards west and take an easterly direction. These winds are known as 'Trade winds'. These are extremely steady winds. So they derive their name from a German word meaning 'track' or a 'steady wind blowing in a constant direction.' In the northern hemisphere, due to their

deflection to their height they blow from north-east and hence they are termed as North-East Trade winds. In the same manner, the wind blowing from the sub-tropical high of southern hemisphere blow from south-east. They are known as South-East Trades.

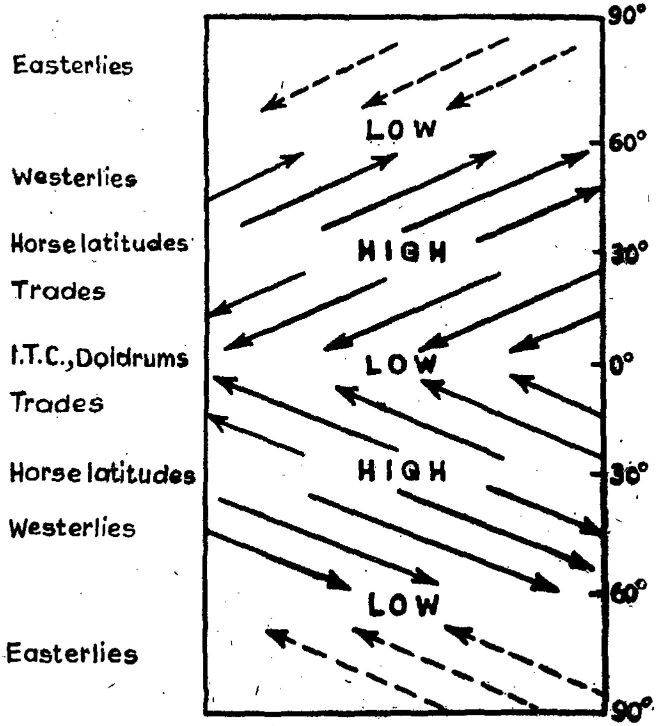

FIG. 10.4 Idealized Arrangement of Earth's Surface Winds

Both north-east and south-east trade winds converge at or near the equator. This is known as the zone of Inter-tropical convergence and is characterised by the absence of horizontal winds. But the convergence of winds makes it to ascend and yield heavy rainfall.

Westerlies

The name 'westerlies' is given to the winds blowing from the Sub-tropical high to Sub-polar low in both the hemispheres. Westerlies blow from south-west to north-east and north-west to

south-east in the northern and southern hemispheres respectively. Owing to the absence of land masses in the higher latitudes of southern hemisphere, the winds blow steadily with a great velocity in the zone between 40°S and 60°S. Hence the winds blowing in this zone are termed as 'Brave winds'. The latitudes in which they blow are popularly known as the 'Roaring Forties', 'Howling Fifties' and 'Screeching Sixties'.

Polar Winds

Polar winds blow from the polar high pressures to sub-polar lows. In the northern hemisphere they blow from north-east, and they are known as north-east polar winds. In the southern hemisphere they blow from the south-east and hence they are known as south-east polar winds.

Minor Terrestrial Winds

Major wind belts reveal the fact that they are caused by differences in the presence on a global scale. But the winds formed due to the local variation in the surface conditions are termed as 'minor terrestrial winds'. Their influence is confined only to a fraction of the earth's surface.

Land and Sea Breezes

The most common terrestrial winds are 'land and sea breezes'. They are of periodic type. They usually occur along the sea coasts and large inland water bodies. During day time the land is heated up more intensively than the sea nearer to it. As a result, the air over the sea becomes denser than that of the land. Consequently winds from the seaside move towards the land in order to equalise the difference in pressure conditions The wind from the sea to land during day time is known as sea breeze. It aids to bring down the day time temperature to a considerable extent.

At nights rapid radiation of heat makes the land to become cooler than the sea. Hence the air over the land becomes denser and moves out seawards. This periodic blow of winds during day and night are known as Land and Sea breeze. Their influence is

very much felt along the narrow margins of sea coasts and large inland water bodies.

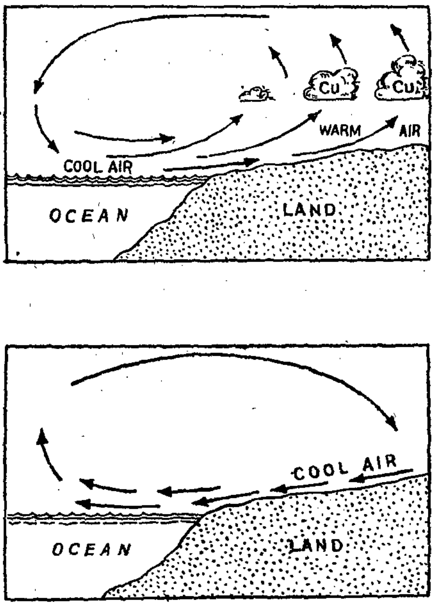

FIG. 10.5 Land and Sea Breezes

Mountain and Valley Winds

Another combination of winds that undergo a daily reversal is 'mountain and valley winds'. During day time the air in close contact with the valley floor and the adjoining slopes is heated by the insolation and becomes light. The air starts moving from the valley up the slopes of the mountain is known as the 'valley breeze.'

On the other hand at nights the mountain slopes become cooler due to terrestrial radiation and the air which comes into contact with the slopes become denser. Due to its weight it comes down the slope and it is collected in the valley. This is known as 'mountain breeze'.

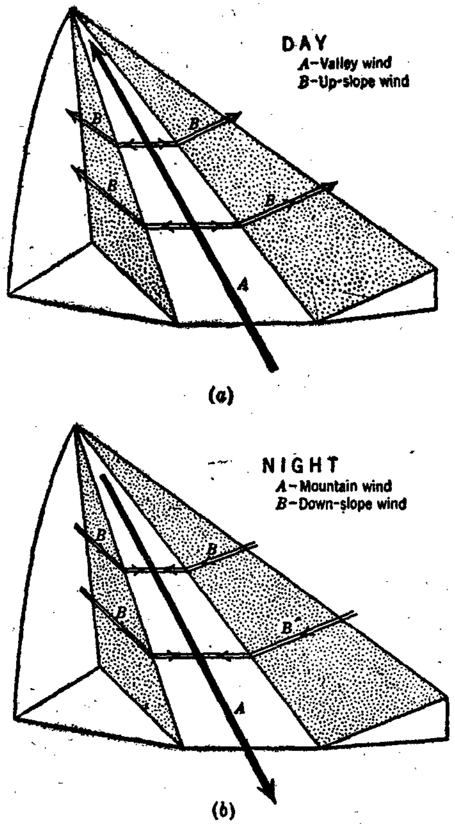

FIG. 10.6 Mountain and Valley Winds

Chinook Winds

The name 'chinook' has been given to a type of wind which occurs on the eastern side of the Rockies. On the leeward side of the Rocky mountain the winds from the western side descend along the slope. While descending the air gets warmed up. It usually occurs at a rapid rate. This leads to a considerable rise in temperature, about 15 to 20°C within a few hours. Due to the rise in temperature the snow melts. So it has been given the name 'chinook' meaning 'snow eater' in the Red Indian Language.

Foehn Winds

This is also like 'chinook' but is found in the Alps. Hence it is often referred to as 'European Chinook'. During the winter the warm dry winds blowing from the southern side descend along northern slope. While descending its temperature increases. The rise in temperature aids to hasten the ripening of grapes in autumn and to melt the snow rapidly in the late winter.

In numerous places winds associated with particular storms or pressure conditions occur with some regularity and are characteristic of the weather of a given locality. The 'loo' of the plains of India, 'Norwesters' of Bengal, 'Harmatten' of Guinea coast of Africa, 'Siracco' of Sicily, 'Pampero' of Argentina and 'Blizzards' of United States are some of the examples.

General Circulation of the Atmosphere

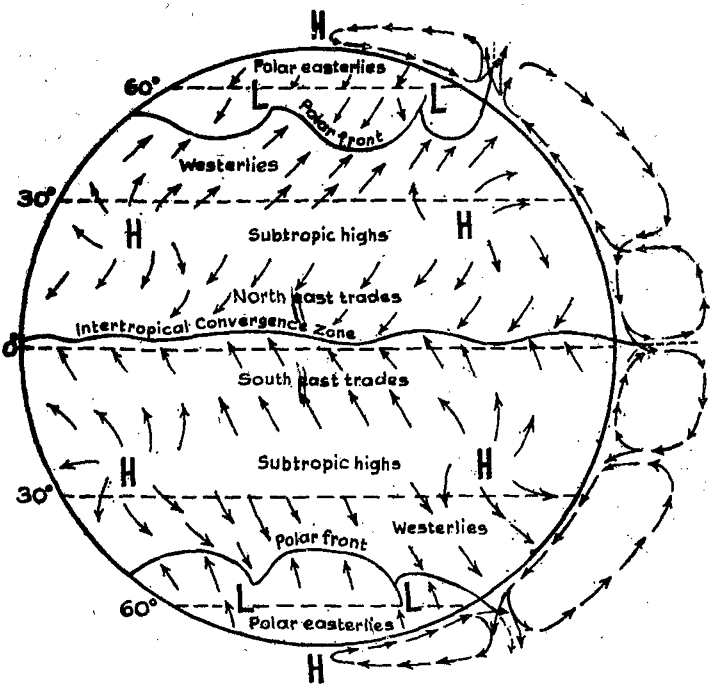

FIG. 10.7 Idealised Arrangement of Winds and Pressure in the General Circulation

The differential heating of the atmosphere by insolation creates a difference in pressure between latitudes and the air from a high pressure tends to move towards a low pressure. The winds from the sub-tropical high pressure to Equatorial low and Sub-polar low and winds from the polar high to sub-polar low complete the surface circulation of atmosphere in the northern as well as southern hemisphere (Fig. 10 7).

Upper Level Waves and Jet Streams

Continuous convergence and ascending of air in the low pressures and descending and divergence of air in the high pressure areas require an exchange of air from the upper levels. This exchange of air requires a continuous flow of air at the higher levels from the equatorial region to the sub-tropics and from the sub-polar lows to the sub-tropical as well as polar highs. This requirement is met by the presence and activities of westerly waves found aloft. But at the higher levels the flow more or less follows the parallels of latitudes than is the case at the surface.

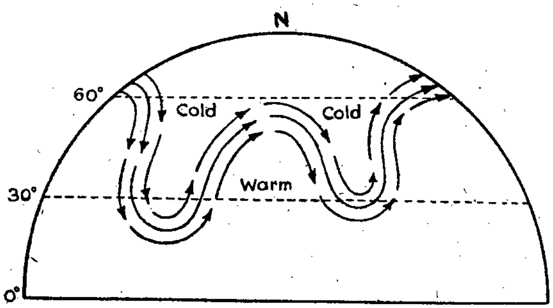

FIG. 10.8 Upper Atmosphere Winds and Jet Streams

These upper waves at several kilometres above the surface, follow giant, undulating paths. Their wavelengths vary between 3000 and 6000 km with 3 to 6 circum-polar waves. These waves correspond to the surface paths of low pressures and high pressures. They are often stationary over a long period of time but the winds within the wave pattern blow at greater speeds. The wind speed is found to be maximum in the jet

streams. Jet streams are narrow bands of high velocity winds that follow the wave path. The sub-tropical jet stream is a fast, narrow stream of air travelling at velocities from 150 to 500 km. per hour. It is well developed and reaches its poleward location in the summer. There are two more jet streams in each hemisphere. They are polar front jet streams and polar night jet stream.

Monsoons

In the words of Trewartha 'the term monsoon may be applied to any wind system in which there is a reversal of the prevailing wind direction between winter and summer'. The name 'monsoon' appears to be derived from the Arabic 'Mansin' or from the Malayan 'Monsin' meaning season. But in the usage the word not only refers to seasonal winds but also to the winds caused by differential heating of the land and sea.

The popular view is that the monsoons are of thermal origin. During the summer season the landmass becomes hotter than the surrounding sea. Hence a pressure gradient is formed when the sea forms the region of a high pressure and a low pressure develops over the land. As a consequence the winds tend to move from the high pressure region to low pressure region i.e., from the sea to the land. Since the winds are of maritime origin (sea origin), they carry abundant moisture with them and give rain over the land.

During the winter months the sea becomes the area of low pressure and land becomes the region of high pressure since the sea surface is warmer than that of land. Thus a reversal of wind movement takes place. The winds begin to move from the land to sea. Because of the fact that these winds originate over land they are dry. Owing to this, the winter monsoon is of less important than the summer monsoon. The winter monsoon occasionally gives rise to rainfall and moreover the winds are not only dry but cold also.

But doubts have been raised whether the monsoons are of purely thermal origin. In recent times theories have been put forth that there is a strong relationship between the latitudinal shift in

the wind belts and the on set and withdrawal of monsoons. After the Second World War, data related to upper air are increasingly available. Recent theories also reveal that there is a close association between the upper air condition and the surface weather conditions. Monsoons are considered as part of the general circulation of the atmosphere.

Monsoons are better developed in Asia than any other part of the world. The Asiatic monsoon provides a classical example of monsoons. Northern Australia, Gulf of Guinea of Western Africa, parts of East Africa and in south-eastern United States are some of the areas where monson type of wind systems are prevalent.

QUESTIONS

I. Short answer questions :

1. Define atmospheric pressure. How is it measured ?
2. Why does the pressure decrease from lower altitude to higher altitude ?
3. What is 'Isobar' ?
4. What is meant by pressure-gradient ?
5. Why do the winds in the southern hemisphere are deflected towards left ?
6. What is a wind ?
7. Write short notes on :
   (*a*) Doldrums
   (*b*) Sub-tropical high pressure
   (*c*) Sub-polar low pressure
   (*d*) Polar high
   (*e*) Trade winds
   (*f*) Chinook winds
   (*g*) Foehn winds
   (*h*) Jet streams.

II. Long answer questions :

1. Write an essay on the general circulation of the atmosphere.
2. Give an account of the origin of the monsoons.

CHAPTER XI

HUMIDITY AND PRECIPITATION

Water present in the form of water vapour in the atmosphere is known as **humidity**. When air and water come into contact with each other exchange of particles takes place. Water particles in the form of vapour enter into the air. This process by which water is converted from liquid into gaseous form is known as evaporation Two-thirds of the earth's surface is occupied by water. This forms the major source of evaporation. Moist soil and vegetation also form the other minor sources of evaporation.

The atmosphere content of the water vapour varies from 0 to 4% by volume. But it is the single most important variable which controls the local weather. It is important because of the following reasons :

(1) It is the source of precipitation.

(2) It is the absorber of terrestrial energy.

(3) It also acts as a store-house of heat for the atmosphere.

Measurement of Humidity

Humidity present in the atmosphere may be expressed in various ways. The atmospheric pressure also includes the pressure exerted by the water vapour. This is known as 'Vapour pressure'. It is expressed in the same units as the atmospheric pressure, i.e. in millibars.

Specific humidity is the weight of water vapour per unit weight of natural air. It is usually expressed as the number of grams of water vapour present in one kilogram of natural air. Humidity is also expressed in terms of Absolute humidity. It is defined as the weight of the water vapour per unit volume of air. It is expressed

in the number of grams of water vapour contained in a cubic centimetre.

Relative humidity is the most often used term to refer the humidity. It is usually expressed as a ratio or percentage. It refers to the amount of water vapour actually present in the atmosphere in comparison with the maximum amount that could be contained under saturation at the given temperature and pressure.

Saturation, Dew Point and Condensation

When air ascends from a lower to higher altitudes its temperature decreases. Its capacity to hold moisture also decreases i.e. relative humidity increases with decreasing temperature. The level at which the actual amount of water vapour present in the air reaches the amount which it could hold at a particular temperature is known as **saturation level**. At this level or point the relative humidity is 100 per cent.

Dew point refers to that temperature at which saturation occurs. If the air is further lifted upwards it's temperature will decrease below the dew point. At this temperature the water holding capacity decreases and it can no longer hold that amount of water vapour. It begins to release the excess water vapour in the form of tiny ice particles. This process in which the water vapour is converted into solid or liquid particles is known as **condensation.**

If the relative humidity is close to the dew point only a slight amount of cooling may be required before condensation. Whereas in the case of hot dry air mass whose relative humidity is at a lower level, large amount of cooling is required. Therefore the two variables which control condensation are :

(1) The relative humidity of the air and

(2) The amount of cooling required.

If condensation takes place at or above 0°C, it will be in the form of liquid. If condensation occurs below 0°C the resulting condensation will be in the form of tiny ice particles.

Forms of Condensation

Condensation can be produced by several methods. Forms of condensation depend upon the method by which condensation

occurs. The method by which condensation occurs can be classified into :

(1) Condensation occurring at or near the surface and

(2) Condensation occurring at a higher level.

(1) Condensation at or near the Surface

When the moist air comes into contact with the cold objects or cold surface or due to mixing of the warm and cold air masses, condensation may result. This condensation is usually of small scale. The forms of condensation which occur near the surface of the earth are dew, white frost and fog.

Dew and White Frost

Dew and white frost are the result of condensation not in the air but because of the surfaces of solid objects exposed to the moist air. During the long clear winter nights the solid surface exposed to the air becomes cold due to radiation. The air comes into contact with these objects are chilled. As a result, condensation occurs on the surface of the objects themselves. If condensation occurs at a temperature above 0°C the product will be in the form of **dew** and if it occurs below 0°C the condensation will be in the form of **white frost**.

Fog

Fog is the result of radiation, conduction and mixing of cold and warm air masses. The **dew** is formed when the air comes into contact with some cold objects and condensation takes place on the surface of the objects. But **fog** is formed when condensation occurs within the air as a result of cooling throughout the layer overlying the cold surface of the earth. Minute droplets of water are suspended within the layers of the atmosphere. It affects the surface visibility and is injurious to crops.

Fogs are of two types. They are :

(1) Radiation fogs

(2) Advection-radiation fogs.

Radiation fogs

The common mist forms a very good example of this type of radiation. These fogs result due to the loss of heat by radiation and condensation from the earth's surface. As a result, temperature of the overlying air mass is also reduced below dew point and condensation takes place.

Radiation fogs are mostly prevalent over the industrial cities where dust and smoke from the chimneys accelerate the process of condensation and the formation of fogs.

Advection-radiation fogs

This typs of fog is formed as a result of horizontal contrast in temperatures when warm, moist air moves over the cold surfaces. The contrasting characteristics of land and water make it ideal for the formation of these fogs along the sea coasts and also along the large inland water bodies. During summer, warm air from the land moves over the comparatively cool sea surface. The air gets cooled and condensation takes place in the form of advection-radiation fog. During the winter months the warm air from the sea moves over the cold landmass causing advection-radiation fog. Hence it is common over the land in winter and over the sea in summer.

(2) Condensation at High Altitudes

Condensation occurring at high altitudes is usually of large scale. This type of condensation is generally associated with the formation of clouds. Cloud in fact is also mist formed in the higher altitudes. If we move from a lower altitude to a higher altitude the temperature gradually decreases. The rate of decrease of temperature is 6°C for every 1000 m of ascent. This is known as **normal lapse rate.**

But when a parcel of air moves up, it comes under lesser pressure. Hence the air expands, the temperature falls down. On the other hand, when the air descends it is subjected to greater pressure and its volume decreases. Hence its temperature and density go up. The rate of increase or decrease is not the same as that of normal lapse rate. When the air is not saturated it decreases at a rate higher than that of normal lapse rate. The rate of

decrease of temperature is 10°C per 1000 m of ascent and is known as **dry adiabatic rate.**

As soon as the air reaches the condensation level, where clouds begin to form, the rate of cooling is lower than that of dry adiabatic rate. Above the condensation level, water vapour is converted into liquid and solid particles and the latent heat are released. This heat of condensation retards the rate of cooling of the air mass. The rate of decrease is about 3°C per 1000 m and is termed as **wet or retarded adiabatic rate.**

Clouds and Cloud Types

Clouds reflect the processes that take place in the atmosphere. They are good indicators of prevailing weather conditions. Because of these reasons, they are useful in forecasting the weather. Clouds are classified on the basis of their form and altitude. They are grouped under the following categories:

(1) High clouds (Mean lower level 6100 m).
(2) Middle clouds (between 2000–6100 m).
(3) Low clouds (Mean upper level 2000 m).
(4) Clouds with vertical development.

(1) High clouds

This type of clouds is found at elevations between 6000 and 10500 metres. Cirrus (Ci) are thin feather-like clouds with a fibrous structure and a delicate silky appearance. When arranged in patterns they reveal the forthcoming bad weather. Cirrostratus (Cs) usually cover the entire sky. They produce a halo around the sun and the moon. Cirrocumulus (Cc) are arranged in groups and are often formed as mackrel or buttermilk sky.

(2) Middle clouds

This type of clouds includes Altostratus (As) and Altocumulus (Ac) and are found at heights between 2000 and 6100 metres. They have the appearance of a high, grey sheet with a fibrous structure.

(3) Low clouds

This type of clouds consist of stratocumulus (Sc), Stratus (St) d Nimbostratus (Ns) and are found at levels below 2000 metres

from the earth's surface. Stratocumulus clouds are seen in the grey overcast sky in large semi-circular form with thicker masses in between. Stratus clouds are low, grey clouds producing general overcast conditions. Nimbostratus clouds are thick clouds without any particular shape. They are usually associated with continuous drizzling.

FIG. 11.1 Types of Clouds

(4) Clouds with vertical development

This type of vertical clouds are found often to reach height of 6100 m. The upper part of the cloud appears like a cauliflower with a dome at the top. The base is nearly horizontal. Cumulonimbus clouds have a great vertical development. They are anvilshaped and are always associated with thunder-storms.

Precipitation

Ascending air may condense and form clouds. But precipitation may not result. As the size of the cloud particle is usually 1/8,000,000 of a rain drop, it is too small to fall. When condensation occurs, the hygroscopic nuclei present in the atmosphere start attracting tiny water particles. This process continues till the drop attains a sufficient size so that it can fall.

The clouds may pass on without yielding precipitation. This is mainly due to the absence of sufficient amount of hygroscopic nuclei in the atmosphere.

Forms of Precipitation

The resulting precipitation would be of various forms depending upon the rate of falling, temperature at which condensation occurs, the surface temperature, etc. If the condensation occurs at a temperature above freezing point, the resulting precipitation would be of liquid form. If the temperature is well below freezing point at the time of condensation, the water vapour may directly be converted into ice crystals (sublimation). As a consequence the precipitation would be in any one of the forms of solid condensation such as snow, sleet and hail.

Precipitation that falls on the surface in a liquid form is known as **rain.** This is the most common form of precipitation. Rain drops may freeze or partly freeze as they fall through the air. This resultant form is known as **sleet.** **Snow** is the result of direct conversion of water vapour into ice crystals. Rapid uplift of airmass causes quick cooling of the atmosphere. Sudden cooling and release of water vapour result in the unusual form of condensation known as **hail.** Hailstone stones may range from 0·5 to 5 cm and are extremely destructive to crops and light buildings.

Types of rainfall

Uplift of airmasses result in rainfall. But the processes that cause the uplift of airmass determine the type of rainfall. The types of rainfall may be classified into three and they are :

(1) Convectional rainfall
(2) Orographic rainfall
(3) Cyclonic or frontal rainfall

(1) Convectional rainfall

When the air is heated by the warm earth surface from below' it becomes less dense and moves up. While ascending, it becomes cold and condensation begins. As the air continues to rise beyond the condensation level rainfall results. This type of rainfall is known as **convectional** rainfall.

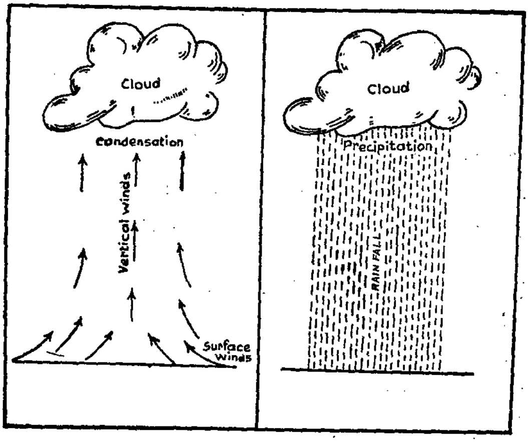

FIG. 11.2 Convectional Rainfall

(2) Orographic rainfall

Sometimes the warm, moisture-ladden winds are forced to ascend due to some obstruction like hilly ranges, etc. in their way. This ascending results in cooling followed by condensation and rainfall. This type of rainfall is known as **orographic** rainfall.

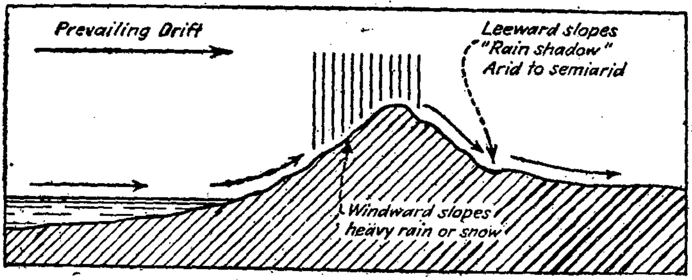

FIG. 11.3 Orographic Rainfall

(3) Cyclonic or frontal rainfall

When two different types of airmasses move towards each other, they cannot mix easily. The warm airmass, because of its lesser density moves over the cold airmass. The ascending of the warm air mass gives rise to rainfall and this type of rainfall is named as **Cyclonic** or **frontal** rainfall.

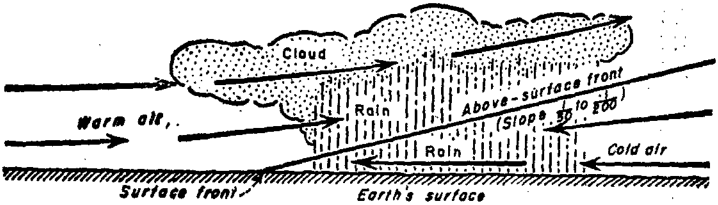

FIG. 11.4 Cyclonic or Frontal Rainfall

Distribution of Rainfall

The amount of rainfall characterizes the physical environment of a particular locality. The amount of rainfall received varies from place to place and from season to season. A number of factors like accessibility and distance from the oceans which are main sources of moisture, the nature of relief, direction of wind, etc. affect the amount and distribution of rainfall.

Very heavy rainfall of over 200 cm are received in the equatorial belt, the favoured mountain slopes along the western coasts in the cool temperate zone and the coastal areas of monsoon lands.

Areas adjacent to the regions receiving very heavy rainfall and coastal areas of warm temperate zone, receive heavy rainfall ranging from 100-200 cm. Central areas of tropical lands and the eastern and interior parts of the temperate zone receive moderate rainfall varying from 50-100 cm.

Light rainfall ranging from 25-50 cm are received in the rain shadow areas on the leeward side of the mountains, the interior of the continents and areas in the high latitudes. The arid deserts and the western margins of continents in tropical lands receive scanty rainfall. The amount of rainfall in these areas is less than 25 cm.

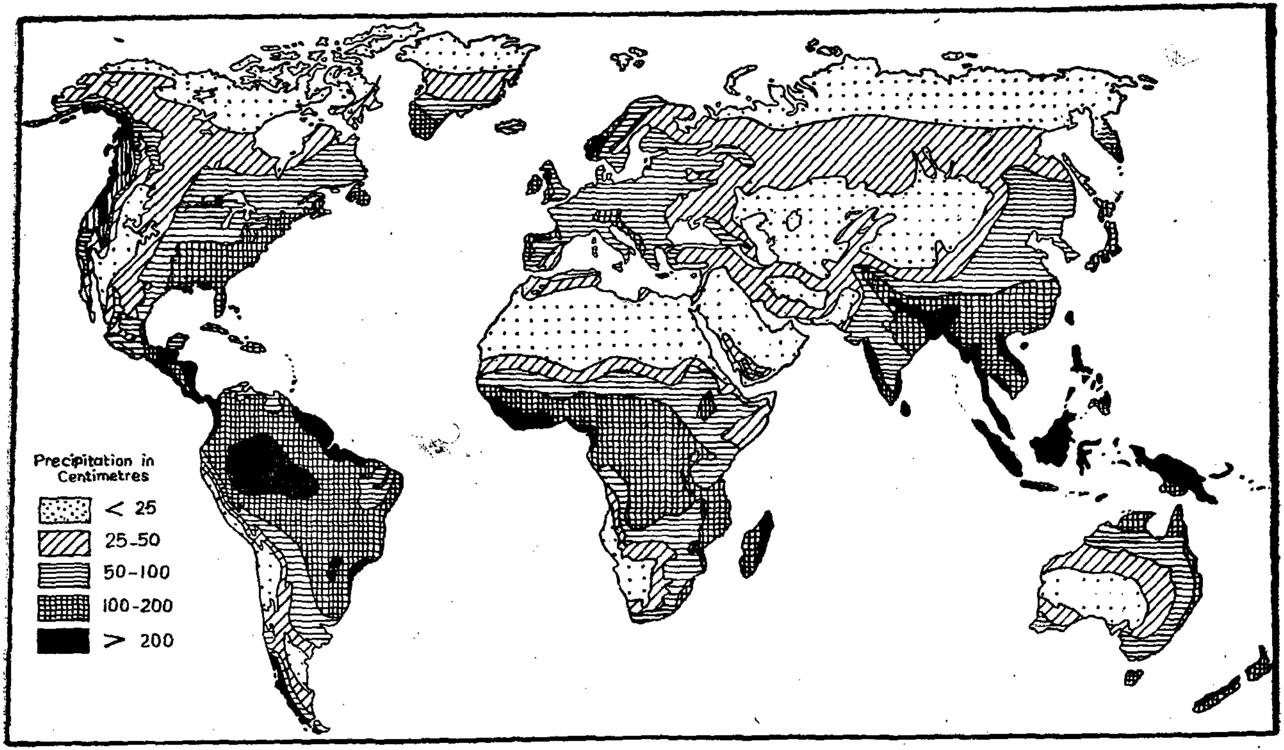

FIG. 11.5 Distribution of Average Annual Precipitation

QUESTIONS

I. Short answer questions :

1. Define humidity.
2. What is evaporation ?
3. Define the term vapour pressure.
4. What are the various ways of expressing humidity ?
5. What do you mean by Dew point ?
6. What do you understand by 'Condensation level' ?
7. What are the various forms of condensation that are taking place at or near the ground ?
8. Define the term 'dry adiabatic rate.'
9. What are the various forms of precipitation ?
10. Mention the types of precipitation.

II. Long answer questions :

1. Classify the clouds on the basis of their structures, locations and types of weather associated.
2. Give an account of the world distribution of precipitation.

CHAPTER XII

AIRMASSES AND FRONTS

A body of air which comes and rests over a region for a considerable period of time, acquires the properties of that region. When it moves over another region it affects the prevailing weather conditions of that region. An airmass may be defined as an extensive body of air whose horizontal temperature and humidity characteristics are uniform at different levels. The region from which the airmass acquires its properties is termed as its **source region.**

Ideal conditions for the development of an airmass:

(1) Extensive homogeneous areas

(2) Light and divergent surface winds

Extensive uniform area favours the formation of an airmass in conducting heat uniformly throughout the portion of the atmosphere which comes into contact with it. Uneven terrain or an area comprising of both land and water does not favour the development of airmasses since the differential heating fails to provide homogeneous conditions. On the other hand the airmass *should be stable for a considerable period of time so that it can* acquire the characteristics of the source region. High pressure regions with their subsidence and divergent winds provide ideal conditions for the formation of airmasses.

Arctic plains North America and *Eurasia in winter* and sub-tropical and tropical oceans in summer form the ideal source regions.

Classification of Airmasses

The characteristics of the airmasses are derived from the source regions. Hence the classification based on their source

regions would be very useful in forecasting the weather. World airmasses can be grouped under 7 categories :

(1) Arctic and polar continental
(2) Polar maritime
(3) Tropical continental
(4) Tropical maritime
(5) Equatorial
(6) Monsoon
(7) Superieur

(1) Arctic and polar continental airmasses

These airmasses are characterised by cold and dry winds since they originate from the high latitudes. In winter, the airmasses occupy the snow fields of Arctic and snow covered portions of North America and Eurasia. In summer only northern most part of the continents of Eurasia and North America are occupied by polar continental airmass.

(2) Polar maritime airmasses

These airmasses originate from the north-eastern part of the Atlantic and Pacific oceans. Their characteristics are also like Arctic and Polar continental airmasses.

(3) Tropical continental airmasses

These airmasses with their warm and dry winds originate from the vast expanses of Africa, Asia, southern Europe and the arid regions of North America. In winter, this airmass is limited only to northern Africa.

(4) Tropical maritime airmasses

The source regions of these airmasses are tropical oceans both in summer and winter. Warm and moist conditions predominate the airmasses.

(5) Equatorial airmasses

Since these airmasses originate in the equatorial regions, they are warm and are full of moisture. They are highly unstable.

(6) Monsoon airmasses

These airmasses form over the land area of south and south-east Asia as well as the adjoining oceans. In winter, they occupy continental position and hence they are excessively cold and dry. In summer, the airmasses are characterised by high temperature and high relative humidity.

(7) Superieur airmass

This airmass does not originate on the surface but is formed in the free atmosphere through descending motion in anti-cyclones in middle latitudes.

Airmasses can also be grouped as warm or cold according to their temperate conditions. Warm airmasses are usually characterised by warm, moist air whereas cold and dry air dominates the cold airmasses.

Fronts

When two airmasses of different temperature and moisture characteristics come together, they do not mix readily with each other. There would be a zone separating them. This zone is termed as the surface of discontinuity. The place at which the 'surface of discontinuity' meets the ground is known as a 'Front.'

The fronts may be classified into three groups :

(1) Warm front, (2) Cold front, (3) Stationary front.

(1) Warm front

If the warm airmass replaces the cold airmass at the time of meeting each other, the resultant front is known as warm front.

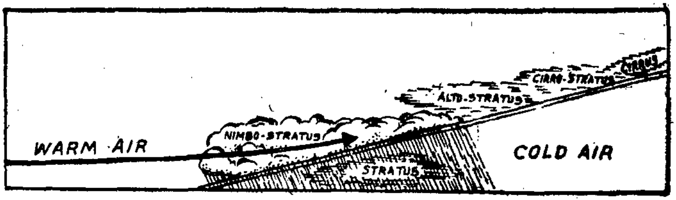

FIG. 12.1 Warm Front

Since a lighter airmass replaces a denser airmass the slope of the surface of discontinuity would be gentle and the warm airmass

ascends along the surface of discontinuity. This ascending causes the formation of clouds and yields rainfall. The climatic consequences of a warm front are a rise in temperature and a moderate rainfall along the direction of the front.

(2) Cold front

If the cold airmass replaces the warm airmass then the front is known as cold front. Because of the fact that a dense airmass moves towards a higher airmass, the warm air is forced to ascend abruptly and the surface of discontinuity would also be abrupt. Heavy rainfall and sudden fall in temperature are the consequences of a cold front.

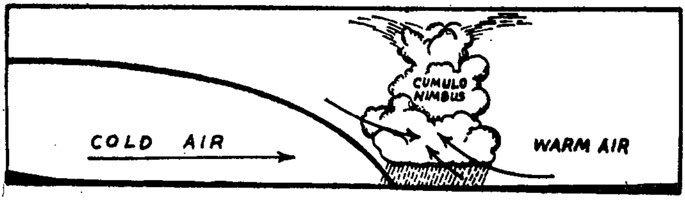

FIG. 12.2 Cold Front

(3) Stationary front

When two airmasses are just juxtaposed together but neither airmasses move towards each other. The resultant front is said to be stationary. But when the warm airmass starts moving towards the cold airmass it will become a warm front or it will become a cold front if the movement is vice versa.

Frontal zones

Frontal zones are named according to the location of the fronts and the airmass which replaces the other airmass. Arctic front separates the Arctic airmass from the Polar airmass. Pacific Arctic front and Atlantic Arctic front along which the Arctic and Polar air invade each other. Pacific Polar front, Arctic Polar front and Mediterranean Polar front are the Polar fronts where the polar airmass meets the Tropical airmass.

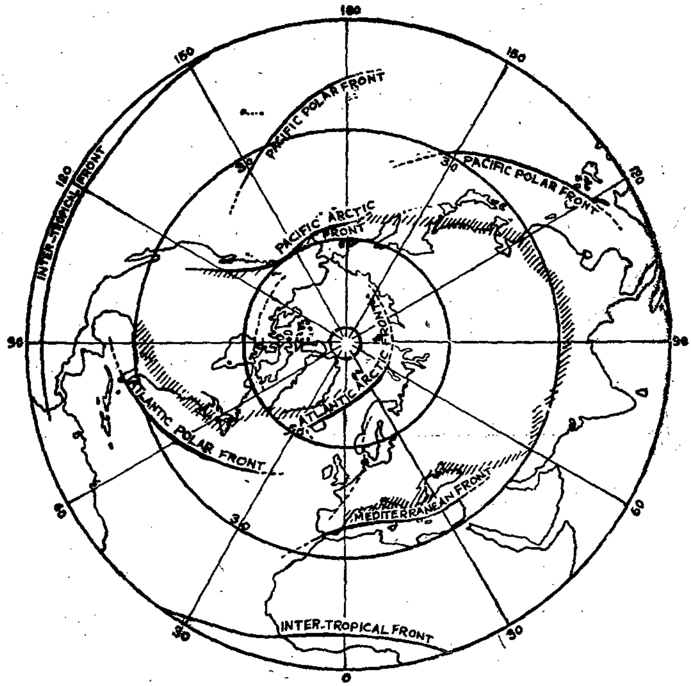

FIG. 12.3 The Major Frontal Zones

Inter-tropical front is the zone at which the tropical airmasses from both the hemispheres converge. But the front is weakly developed since the temperature contrasts are not sharp. The position of the frontal zones oscillates within circle limits according to the shift in the position of pressure belts.

QUESTIONS

I. Short answer questions ;

1. Define an airmass.
2. What is front ?
3. What is ment by a 'source region' ?
4. What are the types of front ?

II. Long answer questions :

1. Classify the airmasses and state how they affect the prevailing weather of a particular place.
2. Give a brief account on the Frontal zones of the world.

CHAPTER XIII

CYCLONES AND ANTI-CYCLONES

There are various phenomena that occur as disturbances in the local weather conditions. These disturbances include cyclones and anti-cyclones which are considered as most important in affecting the local weather phenomena to a great extent.

Cyclones

Cyclones are referred to as 'storms' in the common parlance. A cyclone is the centre of a low pressure shown by closed isobars in weather maps. It is a part of the atmosphere in which the pressure is the lowest in the centre. As a consequence winds tend to converge towards the centre. In accordance with the Ferrell's law winds get deflected instead of blowing straight. This causes cyclic winds from which the name 'cyclone' is derived.

In the northern hemisphere, the winds in a cyclone are deflected to their right. Hence they blow in an anti-clockwise direction. Whereas in the southern hemisphere winds blow in a clockwise direction since they are deflected to their left.

The cyclones that originate in the tropics are known as Tropical cyclones and those which originate outside the tropics are known as Extra-tropical cyclones.

Tropical cyclones

Tropical cyclones are called by various names in various places. They are called cyclones in India, hurricanes in West Indies, typoons in East Asia and willi-willies in Australia. Tropical cyclones are most frequently found in the ocean between 6° to 12° north as well as south latitudes. They generally move towards west and at the western end they take a poleward direction.

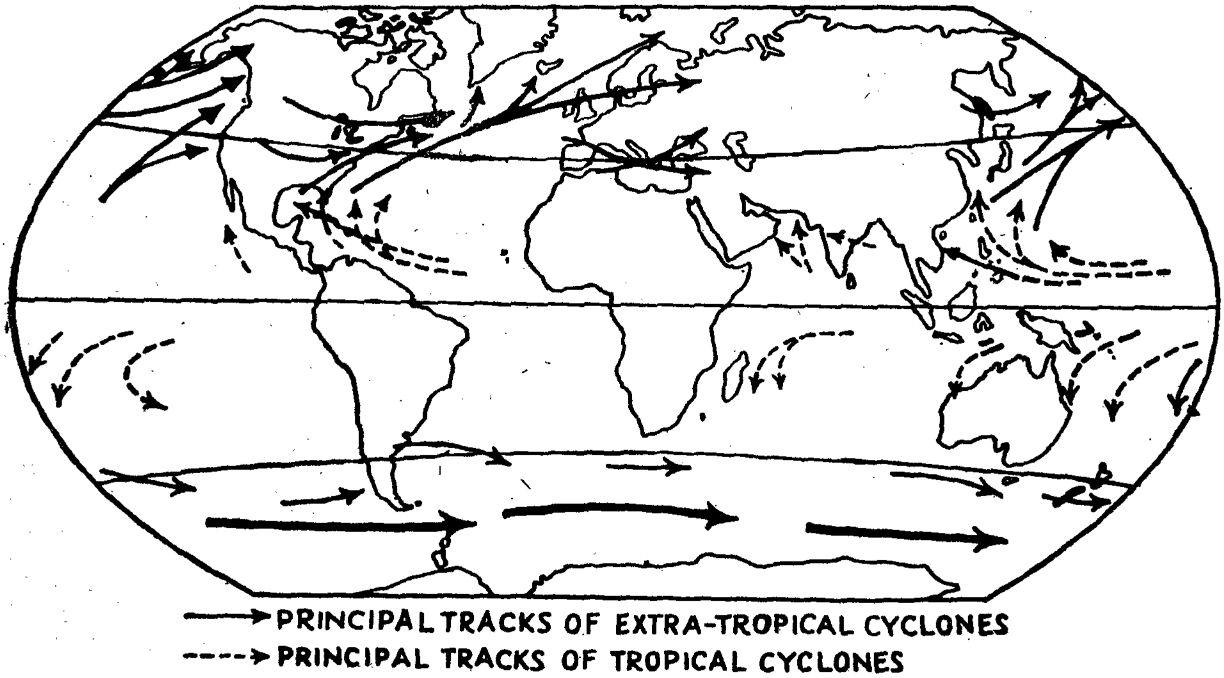

FIG. 13.1 Principal Tracks of Tropical and Extra-tropical Cyclones

Tropical cyclones are usually small in size. The horizontal diameter varies from a few km to several hundred km. The diameter is smaller near the equator than its poleward location since the coriolis least over the equator. The tropical cyclones are shown in a weather map by nearly circular and closely arranged isobars. Hence there is a whirl of strong winds and heavy rainfall. But the centre or 'eye' of a cyclone is free from all these changes. It is characterised by calm, light and variable winds.

Tropical cyclones travel with a moderate speed of about 15 to 30 km per hour. At times the speed at which it travels may exceed 200 km per hour. Tropical cyclones are formed mainly due to thermal instability. Since the coriolis force is weak over the equator, the frequency of tropical cyclones is greatest when the doldrums are far away from the equator. During late summer and early autumn they appear in great numbers.

Extra-tropical cyclones

Extra-tropical cyclones are also known as temperate or middle latitude cyclones. Unlike tropical cyclones, extra-tropical cyclones are very much larger in size. A cyclone in the middle latitudes often have a diameter of several thousand kilometres and even occupy an area of millions of square kilometres. They are elliptical in shape. Larger the size of the cyclone, the lesser will be the intensity.

These cyclones are of frontal origin. Hence these cyclones are frequently found in the middle latitudes which is the meeting ground for the cold dry air from the higher latitudes and warm, moist air from the lower latitudes. In the northern hemisphere, a front is formed when the cold airmass pushes southwards along the ground under the warm air which advances northward. The convergence and rising of the air along the front is accompanied by low pressure which develops to form a cyclone. As the cyclone develops, the pressure gradient is focused towards the centre and the winds tend to move in a cyclic pattern due to the coriolis force.

The extra-tropical cyclones move along the frontal zone from west to east. The average speed of it varies from 30 to 50 km per hour. The rate of movement is greater in winter than in summer.

Anti-cyclones

The term 'anti-cyclone' denotes the conditions opposite to that of a cyclone. An anti-cyclone is characterised by subsidence and divergent winds. Barometric pressure is the highest at its centre and decreases outwards. Because of the coriolis effects it

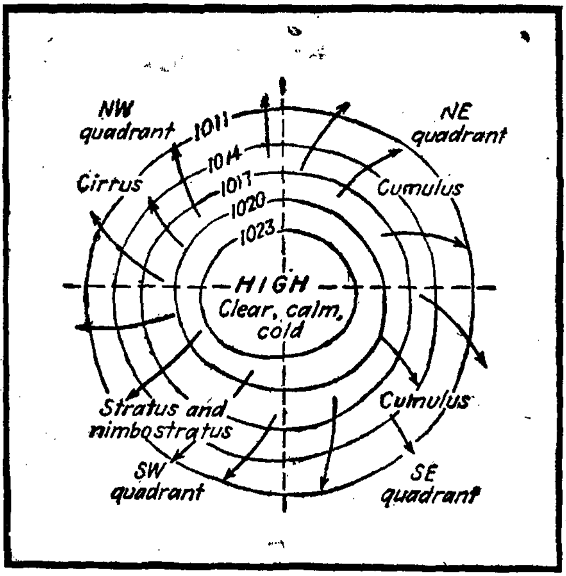

FIG. 13.2 A Model Anti-cyclone

has a clockwise wind circulation in the northern hemisphere and counter clockwise circulation in the southern hemisphere. The persistence of an anti-cyclone over an area reveals a fair weather.

QUETSIONS

I. Short answer questions :

1. What is a Cyclone?
2. What is an Anti-cyclone ?
3. What is an 'eye of a cyclone?

II. Long answer question :

Give an account of the tropical cyclone,

CHAPTER XIV

WEATHER AND CLIMATE

Introduction

Our day-to-day life depends largely upon weather and climate which form the major component of the Physical environment. It has a dominating influence in its way of shaping the landforms. Climate is concerned with long-period manifestations of the weather and the climatic change is usually referred for a longer periods. It can be said that it is even more than statistical meteorology however. The discipline climatology is the science that seems to describe and explain the nature of climate in terms of its change from place to place with respect to the other elements of the natural environment and to human activities.

Weather and Climate

Climate and weather have much in common, but they are not identical. Climate may be defined as the characteristic of weather conditions of a given place, a specific locality or region, averaged over a longer period of time. Whereas the weather is the day-to-day state of the atmosphere and it pertains to short-term changes. The weather of any place is the sum total of the atmospheric variables for a brief period of time. Climate in other words can be called as more than 'average weather.'

Climate always applies to atmospheric conditions for a given period of time—a month, season, year. The average weather conditions showing some uniformity with respect to some of its elements over a period of few months may be described as *season;* and the average weather conditions prevailing between one season and another during a course of a year or more is represented as 'climate of an area' or a 'place.'

Climatic Elements

The climatic elements are :

(1) Temperature

(2) Air Pressure

(3) Precipitation and humidity

(4) Winds

(1) Temperature

The mean temperature and the annual range of temperature are the most important climatic elements. The mean monthly temperature is obtained by adding daily means and dividing it by the number of days in the month The *annual range* of temperature is the difference between the mean temperatures of the warmest and coldest months. The distribution of temperature is commonly shown by means of *isotherms* which are imaginary lines connecting points that have equal temperatures. The isotherm gets deflected when it crosses from land to ocean and vice versa. This is mainly because of the different heating properties of the land and water.

(2) Air pressure

Atmospheric pressure varies from time to time at a given place; it varies from place to place over short distances and on a worldwide scale; and it decreases with increasing altitude. Horizontal pressure differences result primarily from temperature differences. This produces density contrasts and the dynamic causes arising from atmospheric circulation. Atmospheric motions also respond to the rotation of the earth, the effect varying with wind speed and latitude. Mountain barriers and surface friction influence both the direction and speed of air in *motion.*

(3) Precipitation and humidity

Moisture in the atmosphere plays a significant role in weather and climate. Water vapour becomes an important medium (through the process of evaporation) for conveying latent heat into the air. This latent heat functions in the heat exchange as well as in the moisture exchange between the earth and the atmosphere. Humidity is in a general term denoting the amount of water vapour in the air. The amount of water vapour present in the atmosphere directly contributes to the variations of the earth's surface. This is directly to precipitation. The products of condensation when it falls to the ground is known as precipitation (throwing down of moisture). The variability in the distribution and amount of

rainfall depends upon many factors such as the great latitudinal zones of horizontal convergence and divergence, its distance from the ocean, and the nature of relief features.

(4) Winds

It is a more direct climatic element than pressure. Winds of high velocity may be destructive. They directly affect the rate of evaporation and also act as an important element in controlling temperature variations. In a way, pressure and winds are complementary to each other. Because a small change in pressure causes suddenly a change in the velocity and direction of the wind and this in turn brings about changes in temperature and precipitation. These altogether determine the character of weather and climate.

Climatic Controls

The variation of climatic elements from place to place and season to season is determined by the climatic controls. These are (i) latitude (ii) distribution of land and water (iii) the great semi-permanent high and low pressure cells (iv) winds (v) altitude (vi) mountain barriers (vii) ocean currents and (viii) storms of various kinds. These climatic controls act in different combinations with different intensities and thus bring series of changes in temperature and precipitation. This in turn gives rise to different varieties of weather and climate.

The variations in climate from place to place produce a correspondingly large number of climatic types. The combined effects of climatic factors present in an approximately homogeneous set of climatic conditions for an area which is termed as climatic region. The climate of a region depends upon the following important factors:

(1) the composition of the earth's surface
(2) its topography
(3) the prevailing direction of the wind
(4) ocean currents

(1) The composition of the earth's surface

The distribution of land and water surface is not uniform. It is also important to consider that the temperature of the atmos-

phere over the ocean responds in releasing heat much more slowly than does above a land surface. This is because of the different heating properties of land and water. The land gets heated by the process of conduction in which the heat transfers when two bodies of unequal temperature are in contact. But in the case of water surface it acquires heat by the process of convection in which the heat transfer occurs through movement of the air itself. It is also clearly seen that the temperature of a land surface rises much more rapidly than that of a water surface. As a result the marine air is significantly cooler in summer and warmer in winter, than continental air which is at the same latitude. The moisture content of the atmosphere (air) depends upon the surface over which the air is travelling. The transpiration of covering vegetation, witness of the soil and relative location of bodies of water such as rivers, lakes and marshes supply moisture. Apart from the above a significant influence is exerted by the vast ice and snow fields of the Arctic and Antartic regional climates.

(2) Topography

The temperature decreases vertically at a rate of 3° to 5°F per 1000 ft. increase in elevation for the first several thousand feet. Hence the air moving up the mountain slope cools rapidly and further cooling results in condensation, which finally leads to precipitation. Precipitation drops off on the leeward side of the mountain. A classic example of the effect of topography on precipitation is offered by the Himalayan mountains of Asia, the highest mountain ranges in the world.

(3) Prevailing wind directions

The unequal heating in the different latitudes of the earth; combined with the rotation of the earth produces well defined patterns of air movement and circulation. The distance from the sea is one of the important factors in determining the influence of wind over the land surface. Areas enjoying insular or coastal locations have a lower range of temperature which experience more humidity and are apt to receive more precipitation, if the direction of the wind is favourable. E.g. : Andaman Islands, Ceylon and Japan. The areas having continental locations always witness extreme climates with a

greater range of temperature (being very hot in Summer and cold in Winter) less humidity and a scanty precipitation.

In certain areas where the prevailing winds are clearly defined by seasons, they exert a major climatic control for an entire region. This is clearly exemplified by seasonal winds which are otherwise known as 'Monsoons.'

(4) Ocean currents

Ocean currents also affect the climate of the coastal areas. Warm currents make the coastal areas warm and moist whereas the cold currents make the coastal areas cold and dry for e.g.; Californian current or the Canaries current. These currents distinctively result in the latitudinal variation of temperature. Further the meeting of the cold and warm currents brings down the temperature and makes the climate mild.

QUESTIONS

I. Short answer questions :

1. What is climate?
2. How do you differentiate between weather and climate ?
3. What is weather of a place ?
4. Define 'Season.'
5. Mention the important climatic elements.
6. Explain 'annual range of temperature.'
7. Mention the climatic controls.
8. Mention the essential factors which determine the climate of a region.
9. Stress the role of relief in the precipitation process.
10. What are the important reasons for the different patterns of air movement and circulation ?
11. How do ocean currents affect the temperature conditions of the oceans ?

II. Long answer questions :

1. Mention the important climatic elements and their significance.
2. Explain how climatic controls have a direct influence in determining the climate of a region.

CHAPTER XV

CLASSIFICATION OF CLIMATES

The importance of the climatic classification is based on the following objectives (1) to bring order to large quantities of information, (2) to speed of information and (3) to facilitate easy communication. The purpose of the climatic classification is to avoid a great variety of elements to form a limitless number of climates on the earth. Hence this needs a grouping into classes and types. Thus the aim of classification is to achieve the goal of reducing the large number of climates into as many groups as possible. In this way the purpose of any classification system, is to obtain an efficient arrangement of information in a simplified and generalised form.

The climatic region is a subdivision of the climatic type, and hence the type is composed of numerous regions.

A generalised climatic classification is as follows:

(*a*) Equatorial Climate:

1. Equatorial Type

(*b*) Tropical Climate:

1. Tropical Rainy Type
2. Monsoon Type
3. Hot Desert Type
4. Tropical Sub-humid Type

(*c*) Sub-tropical Climate:

1. Warm Sub-tropical — West Coast Type
2. Warm Sub-tropical — East Coast Type
3. Warm Sub-tropical — Continental Type

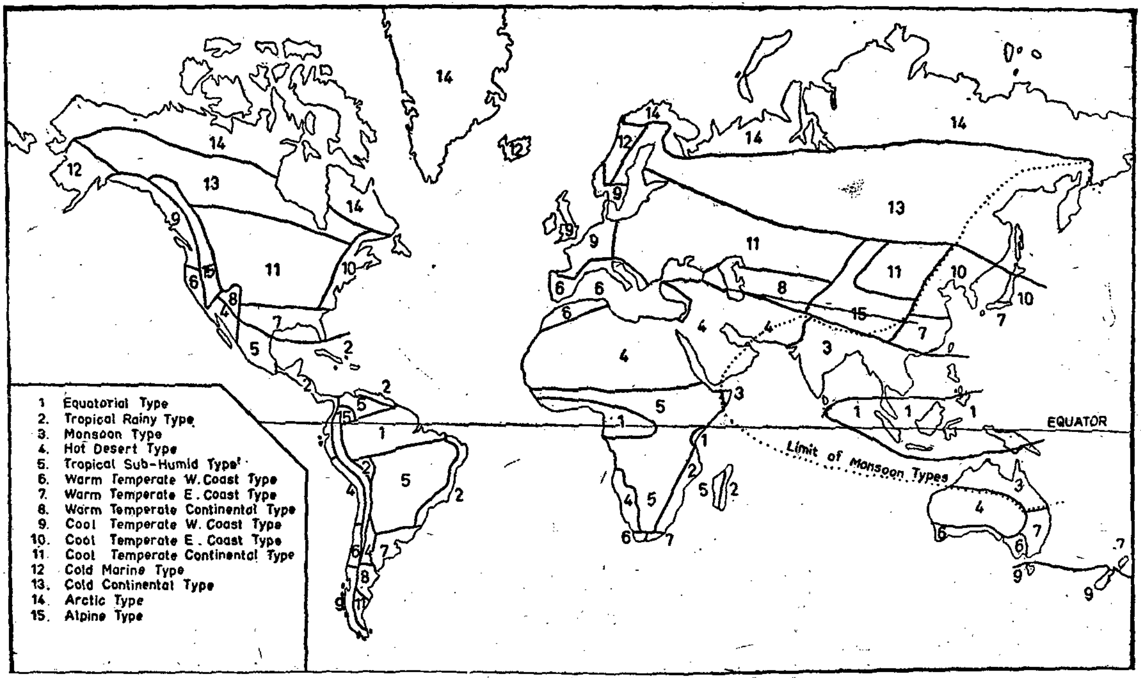

FIG. 15.1 General Classification of Climates

4. Cool Sub-tropical — West Coast Type
5. Cool Sub-tropical — East Coast Type
6. Cool Sub-tropical — Continental Type

(*d*) Extra-tropical Climate:

1. Cold Marine Type
2. Cold Continental Type
3. Arctic Type
4. Alpine Type

(a) Equatorial climate

1. *Equatorial Type*: The equatorial type of climate is found in the equatorial belt within the parallels of 10°N and South latitude.

High mean temperature (about 26°C throughout the year), high relative humidity (about 80%) and heavy precipitation (more than 200 cm well distributed all over the year) are the characteristic features of this type of climate.

The annual range of temperature is less than 3°C and is lower than the daily or diurnal range which is about 8°C. The rainfall is of a convectional nature and it occurs almost every afternoon. It is very difficult to distinguish a well-marked season because of the constant daily mean temperatures and nearly well-distributed rainfall throughout the year.

This type of climate occurs in Congo Basin, Guinea Coast, the Amazon Basin, Malaya and Indonesia.

(b) Tropical climate

This type of climate is found next to the region of equatorial type of climate. Its latitudinal extent is confined upto 30° in either hemisphere. This group of tropical climates consist of the tropical rainy type, the monsoon type, the hot desert type and the tropical sub-humid type.

1. *Tropical Rainy Type*: This zone occupies the major portion of the equatorial belt. The convergence of the trade winds

along the West Coast confines it to a narrow belt. Along the east coast it spreads out to approximately 26°N and south. This is mainly because of the monsoons and the on-land trade winds which give warm weather and rainfall most of the year.

The annual mean temperatures fall between 26° and 27°C. Whereas the annual range of temperature is about 3°C, the diurnal range may be as high as 14°C. These regions receive orographic as well as convectional rainfall. This is owing to the shifting of the wind belts and the influence of onshore trade winds. The important characteristic of this climatic belt is the violent storms such as cyclones, hurricanes, and typhoons.

This type of climate is found along the coast of Guianas in South America, the east coast of Brazil, the Isthmus of Central America, the West Indies, the coasts of East Africa, Eastern Madagascar and Eastern Asia.

2. *Monsoon Type*: The Monsoon type of climate prevails in a belt of wide latitudinal extent both in the tropics and in the sub-tropical regions. It is mainly confined only to the continents of Asia and Australia.

The characteristic feature of this climatic type is a reversal in the wind direction with the change of season. During the Summer season, the wind is onshore, bringing large amounts of moisture to the land surface. The bulk of the rain falls during this season. The amount actually varies according to the distance from the Sea and the orography of the land. Rainfall is both orographic and cyclonic in nature. Most of the stations do not experience highest temperature in mid-summer but it occurs just before the break of the monsoon. This is because of the cooling effect of the rains in the mid-summer months. In the winter season, the wind is offshore, and hence is cool and dry.

The monsoon lands remain almost dry in this season, except in some parts like Madras coast, which gets rain as the winds are onshore during this season. The wide latitudinal extent of the regions, their marked variation in altitude and relief and the inclusion of both coastal and continental areas make it difficult to generalize any set of figures regarding temperature and precipitation of this climatic belt as a whole.

This type of climate is seen in the South, South-East and East Asia, a region which possesses 50% of the world's population. India, Pakistan, Burma, Ceylon, Indo-China, Japan and parts of China enjoy a typical monsoon climate. In addition to these lands, monsoon climate is also found along the Western Guinea Coast of Africa and in the north and north-eastern Australia.

3. Hot Desert Type : This climatic type is found in the western parts of the tropical lands such as the typical regions as the Sahara, the Arabian desert and Thar desert in Northern hemisphere, Kalahari desert. (Chile) and the Great Australian desert in the Southern hemisphere. The low pressure formed over these regions are thermal in origin. The winds are of land origin, and hence the dryness of it resulting in the occurrence of arid lands, like the Sahara. In addition to this, the sub-tropical anticyclones also cause extreme dryness.

This particular climate is characterised by (1) high summer temperatures and large diurnal variation, and moderate annual variation in temperature. (2) low temperatures during winter season, with scanty precipitation, cloudless sky, extreme dryness, dust and standstorms, rain squalls at very rare intervals, and (3) very sparse vegetation of the steppe type.

The annual range of temperature is less significant when it is compared to the huge diurnal range. For example, in summer, by noon thermometer shows 40°C, in the afternoon often rises above 50°C or 55°C. By night the heat is quickly lost by radiation and the minimum temperature drops below the freezing point. For example, in the Death valley of California, the greatest mean diurnal range of over 40°C is recorded.

The wind direction and the distance from the sea always reduce the humidity throughout the year. For instance. Jacobabad records an average of 10 cm rainfall due to monsoonal effect whereas the Insulah records practically nil. Convectional showers are common after a long interval which amounts to between 10 cm and 15 cm.

4. Tropical Sub-humid Type: This particular type of climate is found between the tropical rainy type on one side and the hot deserts on the other. It is a transitional zone which receives convectional rainfall during the summer season. It remains dry during

the rest of the year because of the influence of the trade winds This type of climate is tropical and continental in character. The duration and the average amount of rainfall varies with increasing distance from the equator. The clear skies influence the daily variation and promote daytime heating and rapid radiation during night.

Since this type of climate is the characteristic of Sudan, it is therefore known as Sudan Type.

The tropical continental climate is found mostly in Africa and in parts of South America. Near the vicinity of the Congo Basin, the climatic belt slowly merges with the Sahara type of climate in the north and extends into Cape Province in the south. This type of climate is found in Guiana, Brazilian Highlands and on the Mexican Plateau in North America.

(c) Sub-tropical climates

Sub-tropical climates are found in mid-latitudes between 30° and 60° in either hemisphere. Both summer and winter seasons are well pronounced. The summer is found to be hot whereas the winter is cool between 30° and 40° latitude as against the cold beyond 40° latitude. Hence for easier representation, the sub-tropical latitudes have been further sub-divided into two zones, the warm sub-tropical (30° to 40°) and the cool sub-tropical (40° to 60°)

On the western side, owing to the influence of the oceans, the temperate zone extends towards the pole. Whereas on the eastern side it shrinks into a comparatively narrow zone and terminates near about the parallel of 50°N.

1. *Warm Sub-tropical West Coast Type:* This climatic belt occurs on the western margins of the continents between the parallels of 30° and 40° in both hemispheres. The apparent migration of the Sun causes change in the pressure belts. In spite of the oscillation of the pressure belts, the climatic belt comes under the influence of trade winds in summer and westerlies in the winter season. The important characteristic feature of this belt is its dry summer and rainy winters.

The winter rainfall is mainly due to the temperature depressions. These depressions tend to shift their track a little towards the equator in the winter season. Winter is mild with the average temperature for the coldest month ranging from 10°C to 12°C. The minimum temperature rarely falls below 6°C. Summer is dry and sunny with the average temperature for the warmest month being 16°C. The maximum temperature usually rises above 21°C. The rainfall decreases eastward with a variation of 35 centimetres to 55 centimetres.

This type of climate occurs around the Mediterranean Sea and hence it is called 'the Mediterranean Type.' This climate is also found in Central California, Central Chile, the South-western part of the Cape Province in South Africa, South-western Australia and in the part of Murray Darling Basin in Southern Australia and the North Island of New Zealand.

2. *Warm Sub-tropical East Coast Type :* This type of climate is found along the eastern margins of the land masses in the same warm sub-tropical zones.

The characteristic feature of this climate is a mild winter and hot wet summer. There is a uniform distribution of rainfall throughout the year with a summer maximum. The summer and the winter rainfall perhaps, it may be the result of onshore trade winds in summer and the depressions in the winter.

The average monthly temperature of the coldest month varies from 10°C to 12°C and that for the warmest month between 23°C and 27°C. The rainfall differs from place to place depending upon situation and aspect. There is also a marked variation from year to year. For example, Buenos Aires has a annual rainfall of 94 centimetres with a normal expected variation of 50 cm to 200 cm.

This type of climate occurs along the south-eastern Atlantic and Gulf coasts of the United States, around the plate estuary in South America in the extreme south-east of Africa and to a lesser extent in the North Island of New Zealand.

Since this type of climate has a pronounced reversal of winds, it is known as monsoon climate or *China Type.* This climate is well adhered to South China and South Japan. The

distinguishing character of this climate is that it brings more dominant summer rainfall.

3. *Warm Sub-tropical Continental Type:* The interior parts of the warm sub-tropical zones witness this type of climate. The characteristic of this type is low precipitation (25 cm) owing to the interior continental location of the areas. These locations enjoy semi-arid conditions. This is mainly due to the occurrence of rainfall on the western side in winter and in eastern parts in summer. These temperature differences are governed basically by altitude with a meagre oceanic influence.

For example, the mean annual temperature of Teheran (about 1200 metres above sea level) is 16°C. The annual range of temperature is very high being as much as 28°C. The mean diurnal range is 10°C in January and 15°C in July. The annual precipitation is about 24 cm.

This type of climate is seen in areas like the Anatolian plateau, the Iranian Plateau, the Seistan Plateau and in the Central plains of the United States.

4. *Cool Sub-tropical West Coast Type*: This type of climate is found in the cool sub-tropical zone on the western side of the continents.

As this area is wholly dominated by the infiuence of westerlies throughout the year, this type of climate is characterised by the non-periodic passage of a series of temperature depressions, interspersed with anti-cyclones, in a continuous state of movement throughout the year. There is almost a uniform distribution of rainfall with a slight winter maximum. The coastal areas are being controlled by the warm currents.

This type of climate witnesses a wide local variation. The climate, however, being truly temperate and marine in character, winter is mild and summer is cool. For example at Valentia in Ireland, the annual mean temperature is about 10°C and the annual range is 8°C. The annual precipitation is about 140 cm. This climate is known as the North-west European Type. Because it is found in the British Isles and in the countries of

North-western Europe. It is also found along the coasts of British Columbia in Canada, the States of Washington and Oregon in the United States, along the coast of Southern Chile, in Tasmania and in the South Island of New Zealand.

5. *Cool Sub-tropical East Coast Type:* The eastern margins of the continents lying in the Cool Temperate Zone witness this type of climate.

The cold currents flowing off the continent make the climate, esp., the winter, much colder and drier when it is compared to the western margins. The winds carry continental characteristics over to the eastern coasts, making them warmer. The influence of cold ocean currents lowers the summer temperatures in the northern portions of this climatic type in the northern hemisphere. Precipitation is well distributed throughout the year and is fairly heavy though less than that of the western margins of the continents. The maximum rainfall occurs along Asia's eastern coast due to monsoonal effect.

For example, for a place like Mukden, the mean annual temperature is 7°C. However, in winter the monthly mean drops down to—13°C and shoots in summer up to 25°C. Thus the annual range is as much as 38°C. The annual precipitation is about 66 cm. The rainiest months of July and August account for more than 30 cm.

This climate is a typical characteristic of Manchuria and the St. Lawrence region in Canada. Henee it is known as the *Monchurian* or *Lawrentian Type.* It occurs in Northern China, Korea, Southern Manchuria, and Central Japan.

6. *Cool Sub-tropical Continental Type:* The Cool type of climate characterises the interior parts of Eurasid and North America in the Cool Temperate Zone. It is essentially a region of temperature extremes.

This climate is identified by the increase in temperature towards inland with a summer maximum of rainfall. The low precipitation in winter in the continental areas is mainly due to the result of vast anti-cyclonic high pressure systems.

In Moscow, the January temperature is—11°C and the July temperature is 19°C. This climatic type occurs in Central and Eastern Europe, West Siberia, interior parts of South Canada and the Northern parts of the United States.

(d) Extra-tropical climate

The extra-tropical climate belt is located in the Cool Sub-tropical Zone, although it lies within the belt of the westerly winds. The distinctive feature of this belt of cold climate is their peculiarity with respect to periods of light and darkness, From west to east, from Canada to Northern Eurasia, there is a wide variety of climates such as the marine, continental and monsoonal. Whereas, these different types of climates are absent in the Southern hemisphere. This is mainly because of the absence of extensive land masses in these latitudes.

Polar (or) Arctic Type : Polar climates are largely confined to the high latitudes of the earth. The characteristic feature of this climate is its extremely low temperature. The annual range of temperature has an altered appearance, since, for instance, at the north pole there is no incoming direct solar radiation for a period of 6 months. No month in the year has a temperature more than 10°C. Winters are bitterly cold and this winter cold is sufficiently severe to develope large annual ranges. Most of the year, the temperature is always found to be below the freezing point and the low precipitation is in the form of a fine blizzard-snow. Since Antarctica is being a high plateau, it experiences a more severe type of polar climate with the temperature never rising above freezing point.

The mean temperature at Barrow point for the coldest month is—28°C and for the warmest month it is about 5°C. The annual range is 33°C. The annual precipitation is about 15 centimetres. This type of climate is found in the extreme north of Alaska and Canada, Labrador, the whole of Greenland, the islands within the Arctic Circle and the region along the northern coasts of the Soviet Union. In the southern hemisphere, this climate occurs in Antarctica.

Alpine Type : The Alpine type of climate is associated with the mountainous type of weather. A wide variability is the

characteristic of mountain climates. This mountain type of climate is found in the Alps, the Himalayas, the mountain chains of Central Asia, the Rockies and the Andes. The temperature changes much more quickly in the vertical than in the horizontal direction transitions from one climatic type to another occur very rapidly with the coast in mountain areas. And this type of climate at higher altitudes of these mountains is referred as '*Alpine Climate.*'

A General Survey of Distribution of Climatic Types :

As already indicated that the main purpose of a classification of climates is to provide a reasonably easy and logical guide that permits a comprehensive survey of the great variety of climatic types. Geographers have developed several useful world classifications with the primary objective of establishing world regions as a framework for the human settlements and land use patterns.

The classification of climates was first attempted by Herbertson in the early of 18th century. Then in 1896, a systematic study of the world climate was done by Sudan. He has made a division of the world into 35 provinces. Each is characterised by a certain combination of climatic elements. According to him, the classification of 1 and 35 are the polar regions; 2 to 21 climatic provinces in the eastern hemisphere and 22 to 34 in the western hemisphere. Followed by this W. G. Kendrew, a British climatologist, who described climates of the continents in terms of the distribution of elements and related genetic factors. His classification mainly considers the subdivision of the continents into geographic regions for the purposes of organised description.

In 1900, a Russian born biologist Wladimir Koppen has developed a climatic classification* in a comprehensive way. It defines the climatic types according to the values of climatic elements especially temperature and precipitation, but without considering the geographical location of the regions where these climatic types are found. The same Koppen's climatic classification was modified by Russell and he stressed the importance of the new climatic classification. In 1931, the American climatologist C. Warren Thornthwaite introduced his first classification of

* Fig. 15,2—See at the end of the book.

climates. The essential features of this climatic classification is the *precipitation effectiveness index*, which relates the precipitation to values of evaporation derived from temperature data, and a temperature efficiency index based on mean monthly temperatures. The abovementioned climates have superceded the general classification of climate since it involves the mathematical derivations.

The Thornthwaite climatic classification maintains a line with Koppen; it expresses the relationship between climate and vegetation in five major humidity provinces; rain forest, forest, grassland, steppe and desert. In 1948, Thornthwaite proposed a concept of potential *evapotranspiration* as a basis for climatic classification. The term evapotranspiration indicates the amount of moisture that would be evaporated from the soil and transpired from vegetation if it were available.

QUESTIONS

I. Short answer questions:

1. What is the purpose of a climatic classification?
2. Define 'climatic region.'
3. Mention the extent of tropical climate.
4. Bring out the climatic differences between warm sub-tropical west coast type and warm sub-tropical east coast type.
5. Bring out the climatic significance of Alpine climate.
6. What is meant by potential evapotranspiration?

II. Long answer questions:

1. Attempt a general climatic classification and explain its merits.
2. Bring out a general survey of climatic classifications.

CHAPTER XVI

CLIMATE THROUGH THE AGES

Introduction

The geographical conditions have always played an important part for the great climatic fluctuations of geological time. The geographical conditions imply not merely the distribution of land and sea, but also other variables (factors), such as the height of the land, the presence of important mountain chains, the vegetative covering, the movements of the sea in ocean currents and the existence of volcanoes. Climate is widely considered as 'static' except on the geological time scale. Climate is always changing because the controlling influences are not the same in all parts of the world.

Climatic Change through the Ages

A schematic table (Table—I) clearly explains different geological divisions with periods. These periods certainly characterise the changes in the Geographical conditions. An understanding of geological divisions is essential to study about the climatic changes from the past to the present.

The collective effects of weather is to make up the climate and the only constant feature of weather is to change. A gradual increase in the mean temperature of even a few degrees could alter the global biotic pattern and may cause dangers to certain forms of life. The climatic change can be divided into three major divisions based on the periods of time and its associated evidence. These are:

(1) Periods of the order of millions of years—Paleo climates

(2) Periods in the last several thousand years whose climates may be interpreted in terms of its natural phenomena during recent geological epochs

(3) Historic time which involves the analysis of climatic records

TABLE I

A Schematic Representation of Geological Ages

Geological Divisions	*Period*	*Geographical Conditions*
Cainozoic:		
Holocene	10,000 years ago	Ice continues to retreat-Glacial period is cut off from the continent—Landscape that we see it today.
Pleistocene	Started about 2 million years ago	Ice sheets and glaciers cover most of Europe, America, Antarctica, and the Himalayas—Ice melts periodically witness rise in sea level. Landscape begins to take on present-day form and appearance—A period of abnormal and extreme climatic changes.
Plicene	Started about 10 million years ago	Continents and oceans begin to take on their present form—Climatic conditions are much like today's but with a broader zone.
Miocene	Started about 26 million years ago; (lasted 19 million years)	Powerful earth movements lead to the formation of the Alps, Himalayas—Climates tend to become more varied; dry and arid in some regions, cool and wet in others.

A Schematic Representation of Geological Ages—(*Continued*)

Geological Divisions	*Period*	*Geographical Conditions*
Oligocene	Started about 38 million years ago	This period witnesses that the landmass grows at the expense of sea—The Alps begin to form—Warm Temperate conditions continue, but parts of the landmass experience a cycle of cool winters.
Eocene and Palaeocene ...	Started about 65 million years ago (lasted 27 million years)	Mountain ranges formed in the cretaceous period continue to grow. Volcanic activity leads to the formation of the Atlantic and Indian ocean—Tropical conditions are more widespread than today but glaciers cover the high mountain ranges.
Mesozoic:		
Cretaceous ...	Started about 136 million years ago (lasted 71 million years)	Period of major mountain building—The Rocky Mountains, the Andes, and many European ranges—The climate continues to be mild causing vegetation to grow abundantly as far north as Greenland, though parts of Australia appeared to be covered by glaciers.
Jurassic	Started about 193 million years ago (lasted C 57 million years)	Much of Asia and Europe including neighbourhood of Britain is invaded by the Sea. The climate is predominantly mild, becoming sub-tropical in some regions later in the period—There is sufficient rainfall to support luxuriant vegetation.

Triassic	Started about 225 million years ago (lasted C 32 million years)	Desert and shrub covered mountains make up most of the earth's land area—Hot dry conditions prevail almost everywhere—Climate becomes wetter towards the end of the period.
Paleozoic:		
Permian	Srarted about 280 million years ago (lasted 55 million years)	A period of considerable earth movements. Lofty Mountains form in Europe, Asia and eastern U.S.A. (Appalachian)—Contrasting climatic conditions—Mainly arid in Northern Hemisphere with occasional warm and humid zones, but ice-age conditions cover much of the Southern hemisphere.
Carboniferous ...	Started about 345 million years ago (lasted 65 million years)	Chief coal-forming period particularly in Northern hemisphere—The land climate is extremely dry throughout most of the period, but in some regions it is warm and moist enough to encourage dense vegetation.
Devonian	Started about 395 million years ago (lasted 50 million years)	A period of extensive mountain building and volcanic activity—Warm and semi-arid climate in North-West Europe and over a large part of North America with heavy seasonal rain—Equable conditions prevail everywhere.

A Schematic Representation of Geological Ages—(Continued)

Geological Divisions	*Period*	*Geographical Conditions*
Silurian ...	Started about 435 million years ago (lasted C 40 million years)	New mountain ranges are beginning to form—Less volcanic activity than in Ordovician times—Generally warm and equable climate, but exceptionally dry in certain areas.
Ordovician ...	Started about 500 million years ago (lasted C 65 million years)	The climate appears warm and even, with no marked climatic zones.
Cambrian ...	Started about 570 million years ago (lasted 70 million years)	No evidence of important mountain building—Climatic conditions are moderately warm and equable.
Proterozoic :		
Pre-Cambrian ...	...	Beginning of the Earth—Earth passes through a liquid state and forms a solidified crust—The surface now forms a barren landscape of mountains, deserts etc.—The hot climate is broken up by a series of Ice-Ages.

1. The Paleo climatology refers little about the earth's climate which is known to the world from the Cambrian period, nearly 600 million years ago. This was the period when life forms began to develop rapidly and the free oxygen content of the atmosphere increased. Fossilised remains of plant and animal life in the various sedimentary deposits provide the major clues to inferences about the duration of the geographical extent of temperature and moisture conditions in early geological history. The paleo climates express a 150 million year period of high temperatures through the Cambrian, Ordovician and Silurian, i.e. between 500 and 350 million years ago.

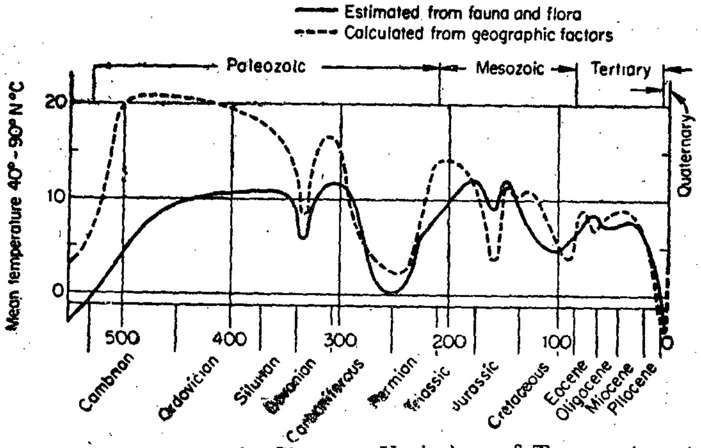

FIG. 16.1 Climatic Change—Variation of Temperature

2. The climatic change of Geological epochs are mainly concerned with great advances or retreats of glaciers, growth of peatbogs, succession of floras, etc. The Ice Age which refers to the past describes the advancement of polar ice towards equator, and as well the retreat of ice during inter-glacial periods. There are four Ages in glaciatian, namely, Gunz, Mindel, Riss, Wurm. These four rhythms of glaciation closely follow the four of the greatest mountain building eras. They may be dated as follows:

(*a*) *Quarternary :* 700,000—20,000 years ago, following the *Alpine Orogeny*.

(*b*) *Premo Carboniferous :* 260,000,000 years ago following the *Hercynian Orogeny*.

(*c*) *Lower Cambrian :* 500,000,000 years ago, following the *Late Proterozoic Orogeny.*

(*d*) *Lower Proterozoic :* 7,50,000,000 years ago, following the *Early Proterozoic Orogeny.*

The further details of glaciation and inter-glacial periods are discussed briefly in the Table II.

TABLE II

Glacial and Inter-glacial Periods

The advancement and retreat of the ice sheets can be grouped into five :

(*a*) The localization of glaciation.

(*b*) The sudden coming of glaciation.

(*c*) Peculiar variations in the height of the snow line of glaciation.

(*d*) Lakes and other evidences of (climatic change) humidity in unglaciated regions during the glacial epochs.

(*e*) Glaciation at Sea level and in low latitudes in the Permian and Proterozoic eras.

(*a*) The localization of glaciation is mainly due to the three important factors viz., (i) temperature, (ii) topography and (iii) precipitation. The variations in localization purely result from the nature and amount of volcanic dust and carbon dioxide present in the atmosphere.

(*b*) The sudden coming of glaciation is one of the strongest arguments against the carbon dioxide theory of glaciation. During this period, there was a rapidity in the growth of trees.

(*c*) There is a close relationship between the height of the snowline and glaciation. The unequal depression of snowline is dependent upon the temperature variations. The actual position of the snowline at the equator during glacial periods appears to be the combined effect of diminished precipitation. This would raise the line when temperature is high and lower temperature brings it down.

(*d*) The presence of extensive lakes, numerous abundant strand lines of salt lakes, and an abundance of coarse material in deltas and flood plains provide evidences of glacial periods. The increase in the level of the lakes may be because of the lower temperature. This would cause less evaporation from their surfaces. For e.g., : Great Salt Lake (average depth more than 40 times great), Lake Bonneville (10 times as large as modern remnant). Solar activity is accompanied by an increase in storminess in the south-western United States in exactly the region where elevated strands of diminished salt lakes are most numerous. This has resulted in the occurrence of semi-arid and desert regions.

(*e*) The occurrence of the widespread glaciation depends on the position and the altitude of the mountains. Uplift alone cannot account for extensive glaciation in sub-tropical latitudes during the permian and Proterozoic periods. A well denoted example is the monsoonal effect on Indian systems of Himalayan mountains.

3. As regards with the climatic change of the Historical epoch, the major, climatic oscillations lasting million of years are due to the major cycles of mountain building and degradation. Their geographical effects include variations in the amount of carbon dioxide and volcanic dust in the atmosphere. Climatic fluctuations of the second order lasting thousands or tens of thousands of years are due to two or possibly three causes. They are :

(*a*) Minor changes in the land and sea distribution.

(*b*) Astronomical changes which include the eccentricity of the earth's orbit, obliquity of the eliptic, procession of equinoxes and possibly by other causes.

(*c*) Long period variations of solar activity.

Another important feature in the case of climatic changes lasting for a few hundred years are mainly due to the variations of solar activity.

Theories of Climatic Change

The astronomical theories explain that the changes in the angle of the earth's axis from its plane of elliptic, would affect the seasons and temperature distribution. The changes in the

eccentricity of the earth's orbit resulted in the variations in the mean distance from earth to sun could affect average temperatures on the earth. As the same case, the procession of equinoxes, refer to the regular change in the time when the earth is at a given distance from the sun. At present the earth is situated closest to the sun in the Northern hemisphere in winter (about January 3rd). The shifting of the earth from its axis at poles is supposed that the geographic poles migrated to their present locations from what are now lower latitudes. This can be indicated by a corresponding shift of the attendant climatic conditions.

Most of the climatic theories have dealt with the possible effects of an imbalance in the earth's heat budget. One of the important hold in this is that the Sun is a variable star. There are changes in the kind and the amount of energy emitted. Theories based on

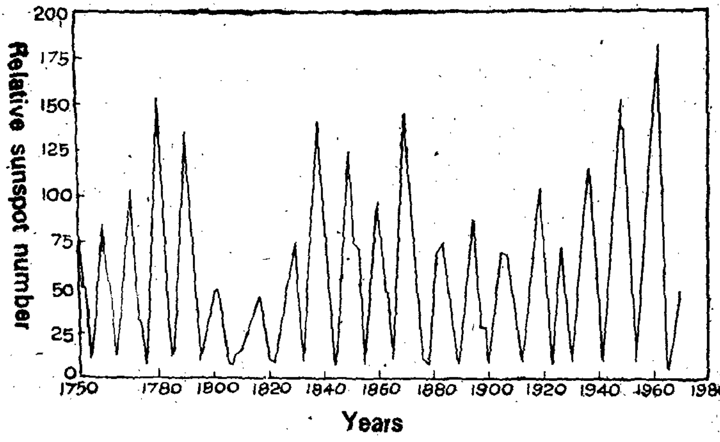

FIG. 16.2 Variation of Mean Sunspot Activity

a changing Sun merge with those concerning Sunspot cycles. The number of sunspots present during the centuries enclose certain facts. The increase of the sunspots are expressed by cooler, wetter weather and greater storminess. If the number of sunspots are lower, there it characterises a warmer and drier period.

Evidences of Climatic Change

A considerable number of evidences reveal that the climatic changes once enjoyed a particular type of climate did not enjoy the same type of climate at present. For example, the cool belts of North America, Europe and central Asia lie today in the temperate region, but in the past when the coal beds were deposited there must have been a luxuriant growth of forests similar to what is found in the equatorial belt today. The evidence of glaciation is found in Rajasthan and Peninsular India. This indicates that these areas must have enjoyed a cold climate in the past. Another remarkable evidence of climatic change is the change of wetter Asia in the past into drier at present. This can be illustrated from habitance to uninhabitance of people.

The general evidences of climatic change are as follows:

(1) Records of floods and droughts. e.g.: Famine occurred in Bihar in 1965.

(2) Records of dates of sowing and harvesting of crops. (These are records of wine harvest in parts of Europe since 1400).

(3) Records of dates of freezing harbours and rivers (winters with ice off the Danish Coast have been recorded since 1350).

(4) The evolution and extinction of more specialised fauna (e.g.: mammoth) and flora.

(5) The evidence provided by rocks are far more satisfactory. For e.g.: boulder clay indicating the glacial climates, salt and gypsum deposits indicating the aridity.

(6) Evidence of Settlements: (e.g. ruined cities) where settlement is possible because of climate. e.g.: Palmyra in the Syrian desert, which it is claimed, must have had a population of more than 1,00,000 but now it has not enough water supply even for a thousand.

(7) Migration of people on a large scale which may be ascribed to, or at least correlated with increasing drought of this home region.

At present we are passing through an inter-glacial period i.e. it is the period where glaciers are retreating northwards because of the Sun's adequate heating.

QUESTIONS

I. Short answer questions:

1. Mention the different divisions of climatic change based on the periods of time.
2. What do you mean by Paleo climates ?
3. Bring out the four major greatest mountain building eras.
4. Stress any two important theories of climatic change.
5. What is Sunspot cycle ?
6. Mention some of the general evidences of climatic change.

II. Long answer questions:

1. What is climatic change ? Give evidences in support of the above.
2. Mention some of the important theories of climatic change and signify its importance.

CHAPTER XVII

WEATHERING AND EROSION

The study of the different characteristic features of landforms and their formation is the basic unit of study in the field of Physical Geography. The study of Landscape is otherwise called as Geomorphology. Various gradation processes account for the different types of major landforms on the surface of the Lithosphere. Of all the processes, Weathering is the first step and most important one too in the modification of Landscape, followed by different agents of erosion. Due to weathering solid rocks around the crust of the earth disintegrate and decay. The chief function of the stream, glaciers, wind, wave and shore currents is to carry the weathered materials from higher to lower levels resulting in a remarkable variety of topographic forms which ultimately reach the sea.

Weathering

The process responsible for the disintegration and decomposition of rocks is called **weathering**. It can be divided into two types based on the actions involved. They are :

(1) Physical or Mechanical Weathering

(2) Chemical Weathering

(1) Physical or Mechanical Weathering

The process of rocks that are physically fragmented or disintegrated without changing their chemical composition by different mechanical actions is called Physical Weathering. It takes place mainly due to the following phenomena :

(*a*) Temperature changes

(*b*) Freezing action of water

(*c*) Plants and animal disintegration

During the process of temperature changes rock cracks and crevices may develop. These cracks may get enlarged due to

expansion of freezing water, the prying plant roots or the disintegration by burrowing animals.

(a) Rock Disintegration Due to Temperature Changes

The crystalline rocks when exposed to strong sunlight get heated. They expand due to the increase in temperature during day time and shrink when temperature falls. These temperature changes split the rocks into debris and the resultant action is called **expoliation.**

(b) Freezing Action of Water

If water enters into the rock joints it may get freezed due to temperature changes. The resultant thaw action of water in rock joints causes the rock fracture. The frost action destroys the rock structure considerably In steep mountain slopes and cliffs where there are numerous joints. The shattered angular rock debris, called screes, will accumulate in the steep foothill slopes.

(c) Rock Disintegration Due to Plants and Animals

The penetration of plant roots and uprooting of trees causes the fracture in rock beds. The burrowing animals contribute to the rock weathering by loosening the ground. Original rock beds also get disintegrated by the activi ties of mankind namely mining, quarrying, deforestation, etc.

All the above-said process occur most actively in areas with cold or dry climate. The places showing extreme temperature and maximum temperature variation are predominantly affected by the Mechanical Weathering processes.

(2) Chemical Weathering

If the rock materials decayed or decomposed along with chemical changes the action is called **chemical weathering.** In nature, only very few rock minerals resist decomposition, but most of them are broken down. The alteration of rock materials by chemical processes is largely performed by rain water. While it runs on the surface, rain water carries various types of acidic and organic substances and forms solutions capable of disintegrating rock. It also acts as an agent and conveyer with the presence of

carbon dioxide and oxygen in it. Weathering of this type is controlled by the concentration and different chemical reactions of the solution. The most important chemical changes that take place in the process of chemical weathering are oxidation, carbonation, hydration and solution.

Oxidation

When rocks are exposed to the atmosphere oxygen present in rain water enters into chemical union with the mineral compounds in the rocks. The decomposed rock is transformed into powdered mass due to **oxidation.**

Carbonation

Rain water, with the dissolved carbon dioxide of the air in it, becomes a weak acid. If it runs on limestone bedrock it dissolves the calcium carbonate leaving the calcium bi-carbonate. This chemical process in rock deformation is known as **carbonation.** This type of chemical weathering is well noticed in the limestone areas of humid regions.

Hydration

The chemical union of water with mineral is called **hydration.** This type of rock mineral disintegration is most effective on aluminium-bearing minerals.

Solution

Water dissolves certain minerals in the rock and forms a solution. The process occurs only when soluble rock minerals are found on the surface. Notable minerals like gypsum and rocksalt most easily dissolve in water. The resultant weathering process is called **solution.**

Since all these processes require the presence of water, chemical weathering takes place most effectively in humid regions. Warm climatic type is also more suitable because high temperature encourages chemical decomposition.

Erosion

The weathered materials accumulated on the surface of the Lithosphere are known as mantle rock or regolith. The process

of removal of these materials from one place to another by various agents is called **erosion**. Erosion process is accomplished by the rivers (running water), glaciers (moving ice), blowing winds, and waves and currents. Numerous actions are involved in the process of erosion. Some of the major actions involved in this process are corrosion, hydraulic action, corrosion or abration, and attrition.

Corrosion

Running water as it moves on the surface, transports certain materials in solution and also certain other materials as are removed from the bedrock. The resultant solvent action of water is called **corrosion**.

Hydraulic Action

Rapidly draining water derives energy and removes some of the surface materials by its force. This process of the removal of rock materials by the running water is known as **hydraulic action**. Water force mainly depends upon the surface slope, volume of water and the load of the stream. For example, in a waterfall, one can see the impact of falling water cutting down very large rock surfaces. When a river is in flood, the flood water cuts and removes the soil of its own embankments.

Abration

Running water removes rock debris and particles of sand and soil and transport them from one place to another. The materials thus removed erode the valley floor and smoothen the bed rocks. This action of bedrock surface erosion by the load of the stream is called **corrosion**. In the desert, the sand particles move forward and backward depending upon the velocity and direction of the wind. As a result the surface rocks get smoothened or polished. This action is similar to corrosion and is called **abration**.

Attrition

The particles of sand and soil and small stones which are used as corrosive tools in course of time get reduced and become smallar in size. This action of erosion in which the corrosive tools get damaged is known as **attrition**.

Transportation and Deposition

The materials thus eroded are transported by various methods. They are solution, suspension, saltation and traction.

Solution

All the soluble particles dissolved by water at the time of erosion are transported over long distances in the form of solution. The transport action ceases while the evaporation exceeds the supply of water and the dissolved materials get deposited. This process of transportation of dissolved materials is called **solution.**

Suspension

As water flows it carries some of the very fine soil particles with it. If there is no flow in the water these particles slowly settle down at the floor of the stream channel. The action of transporting suspended soil particles by running water is known as **suspension.**

Saltation

Depending upon the velocity of the water flow the large and small particles of sand and stones move at intervals. The heavier particles move in a series of hops while the smaller ones are carried till the water has sufficient energy. This type of transportation of materials is called **saltation.**

Traction

But, if the rock debris are heavier the running water drags them along the floor. This dragging of the load is called **traction.**

QUESTIONS

I. Short answer questions :

1. What is weathering ?
2. Mention the different types of weathering.
3. Explain denudation process.
4. What are the different processes of denudation ?
5. Name the various agents of erosion.

II. Long answer questions :

Give an account of physical and chemical weathering.

CHAPTER XVIII

WORK OF RUNNING WATER

Running water is by far the largest agent in the process of removal of material and in the formation of different features of landforms. River erosion is most effective in regions with humid climate and is less effective in dry regions. Two major conditions determine the rate of erosion by rivers. They are the volume of water in the river and the velocity of flow.

Heavy rainfall and steeper slope favour more effective stream erosion. Moving water picks larger particles in greater quantity and transport them. It carries dislodged rock particles by rolling them on valley floor on its course. The debris carried by a river is called its load. While transporting the load it wears down the bed rock. The amount of such wearing away depends upon the quantity and nature of the material being transported. It also depends on the structure of the bed rock.

Running water deposits all or part of its load when its velocity decreases. The load is also deposited where there is a marked increase in the addition of its load. The accumulation of earth materials laid down in water are called **alluvium**. The deposition of these alluvium takes a number of forms.

Alluvial Fan

When a mountain stream descends on a flat plain, the river velocity suddenly decreases. The result is that the transported alluvium gets deposited at the foot of the hill slope. As this deposition of alluvium at the foothills is fan-shaped it is described as an **alluvial fan**.

Flood Plain

Broad expanses of land in stream valleys are built up during excessive run off. Such deposits, known as **flood plains**, accumulate when the speed of the overflow decreases. In many cases, the

ALLUVIAL FAN

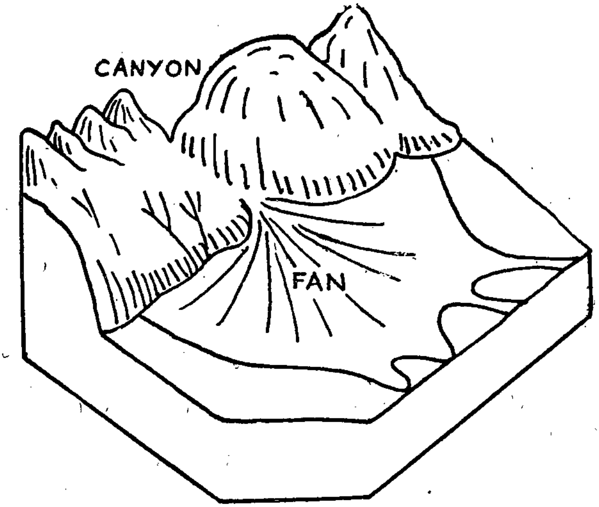

FIG. 18.1 Alluvial Fan

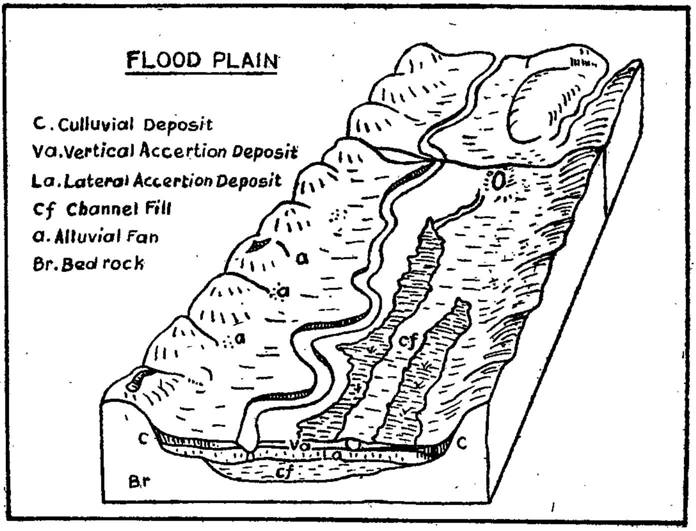

FIG. 18.2 Flood Plain

deposits of material are thickest near the stream itself. This results in the river running on a higher level than the surrounding land surface. The embankment then built up by the stream on either side is called the 'natural levee.'

Delta and Distributaries

The rivers deposit all their load when they flow into the relatively quiet waters of lakes, seas and oceans. This results in the construction of features known as **deltas**. A delta is more or less a triangular shape of alluvial land formed at the mouth of a river. The apex of a delta always points upstream. Since it resembles the shape of the Greek letter (Δ) delta it is named as delta. When deltas are formed, the accumulation of allvium may cause the water course become choked with sand or mud and a number of secondary or distributary channels may develop. The familiar example of this feature is the delta of river Cauvery found in Thanjavur district of Tamil Nadu.

River Valley Formation

The formation of a river valley is the combined effect of the three different actions of river called erosion, transportation and deposition. However, the influence of these three actions varies from the source of the river along its course to its mouth. Hence, the development of the river valley can be studied by dividing three sections along its course. They are (1) The upper course, (2) the middle course and (3) the lower course.

The Upper Course

It is generally found in the hilly or mountainous regions where the river rises having a steep slope or a gradient and cuts deeply into its bed. The process of down-cutting is confined to this section and the river flows in a fairly straight course. At this stage, due to the steep gradient the velocity and transporting capacity of the river is more and valley deepening process attains its maximum. This vigorous down-cutting and greater transporting power of the course of the river valley at this stage is shaped as 'V.' The 'V' **shaped valleys** are commonly found in areas with heavy rainfall, non-resistant rocks and steeper gradient,

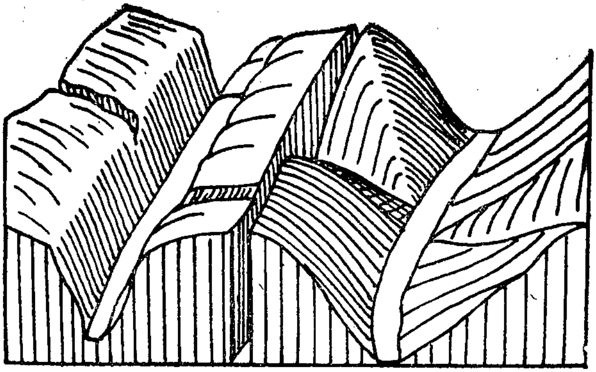

FIG. 18.3 'V' Shaped Valley

When the bed rock is hard and fully resistent in nature, weathering may be insignificant. The vigorous down-cutting process of the river on such surfaces forms a valley with almost steep vertical sides, known as Gorge. The Grand Canyon of Colorado river is a typical example. In India, Gorges are found along the course of the Brahmaputra and the Indus. The Gorges or Canyons with vertical steep walls are also called **'I' shaped valleys.**

Some of the other prominent features that occur in the upper course of a river are waterfalls, rapids, and cascade. Apart from this, valley lengthening is also taking place by headward erosion. The source of the streams is also shifted progressively to higher grounds.

The Middle Course

The river when it reaches lower gradients retardation of down-cutting starts and the valley widening begins. Some of the important processes of valley widening are the scouring and steepening of the channel, soil creep, slumping and landslides. Development of river meanders in the flood plain is a prominent feature in this stage. Due to the decrease in the velocity the winding of streams develops. The winding course of the river in loops is known as **meander**. Due to constant side cutting the directly opposite side of the winding section is eroded fast as in

the Fig. 18.4. The adjacent loops of the winding section become narrower and the river cuts off the loops and flows in a straight course. The cut off loops thus formed is called an **oxbow lake.**

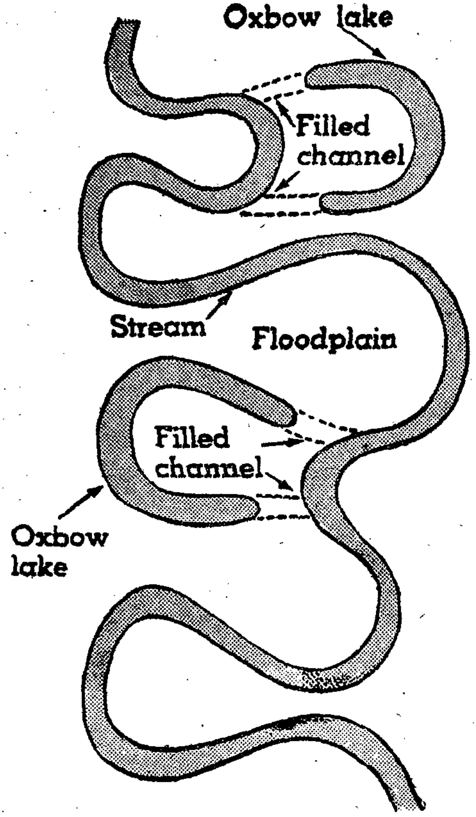

FIG. 18.4 Oxbow Lake in Meandering River Course

The Lower Course

Depositional activity increases rapidly while the gradient decreases on the plain in this stage. Sediments of the river on the flood plain forms different characteristic depositional features. The swinging of river meander and greater widening of the river become more prominent. Due to over flowing of water during

floods, the river spreads out on both sides and builds a raised bank, natural levee on their side. These are different from man-made embankments constructed for flood protection.

The level of the river bed is raised above the surrounding area due to the continuous accumulation of sediments in its own bed. On these sediments the main river flows in a number of channels developing a braided pattern. The delta formation starts at its exit into either a lake or sea. In delta regions, the divided channels are called **distributaries** where these streams enter directly into sea or lakes.

QUESTIONS

I. Short answer questions:

1. What is a Delta ?
2. What is a gorge? Give an example.
3. How are the flood plains formed ?
4. Where and how are alluvial fans developed ?
5. How do waterfalls occur ? Give an example.
6. Name the characteristic features of a youthful river.
7. What are the factors affecting the energy of a stream ?
8. Describe 'oxbow lake.'
9. Give an example for deltaic plain.

II. Long answer questions :

Explain the evolution of landscape features under various stages due to running water.

CHAPTER XIX

WORK OF GLACIERS

The heavy winter snowfall, at higher altitudes and latitudes, where the summer melting and evaporation fails to remove it forms snow fields. Generally snow accumulates over gentle slop s with shaded hollows from sun and well sheltered from the wind. The snow fields grow gradually in depth and surface area. Due to the sufficient pressure exerted on the ice in depth, the ice mass starts flowing outwards from the snow fields. It also starts moving under the influence of gravity force. This moving mass of ice is known as **Glacier**. The Glacier is not as quick moving as the water in a river. In valley heads, Glaciers start creeping slowly downwards as Tongue-like stream of ice.

Types of Glaciers

Three major types of Glaciers are found on the lithosphere. They are :

(*a*) Ice sheets and Ice caps or Continental Glaciers : This type is found in plateau regions. These ice masses creep down in a massive movement slowly towards the margins. This is also called **continental glacier.** Ice sheets of Greenland and Antartica are prominent examples of this type.

(*b*) Mountain or Valley Glaciers : If the ice masses as they move, occupy already existing valleys of mountain ranges they are known as mountain or valley glaciers. Except Australia this type of glacier is normally found in all the continents.

(*c*) Piedmount Glaciers : The ice sheet formed by the coalescence of several valley glaciers spreading out below the snow line over a low land area is known as Piedmount Glaciers. Malaspina Glacier of Alaska is an outstanding example of this type. This glacier covers an area of nearly 4000 sq. kms.

Surface Features of Glaciers

When the ice mass passes through rough surface, glacier bending, declivity and cracks are formed along its course. The Glaciers crack formation leads to the formation of features called crevasses. Commonly there are four types of creavasses found in glaciated regions. They are Transverse, Longitudinal, marginal and bergschrund crevasses.

The transverse crevasses develop across a glacier where there is a marked steepening of floor slope. The longitudinal crevasses run parallel to the direction of flow of the Glacier. Marginal crevasses point upstream from the sides of the glacier, while the bergschrund crevasses are formed at the top of the neve field of a cirque.

Glaciation and Glacial Erosion

The geological work accomplished by moving ice including erosion, deposition and the resulting effects of these processes on glaciated surface is known as **glaciation**.

Plucking action is by far the major action in the process of glacial erosion. The moving ice due to its plucking action does not change its course as in the case of water. Because of the compactness of ice mass, erosion is greater on the floor and the bottom sides of the glaciated valley.

Glaciated Landscape Features

The features developed due to glacial erosion in highlands with well developed valleys are cirque or corrie, Glacial Trough, Hanging Valley, Truncated spur and many others.

Cirque

It is the most common feature of a highland glaciated region. It has an Armchair pattern with steep back and side walls. It is also known as a Corrie in Scotland and CWM in Wales.

A cirque three distinguishing features. They are : (1) The head wall or back wall, (2) The bottom or central depression and (3) The threshold or elevated portion at its opening.

Normally the head wall may be as high as 1000 to 1500 ft. Sometimes it reaches a heigh of 3000 ft. and is also steep. There is no debris left at the bottom of the head wall. The basin is at

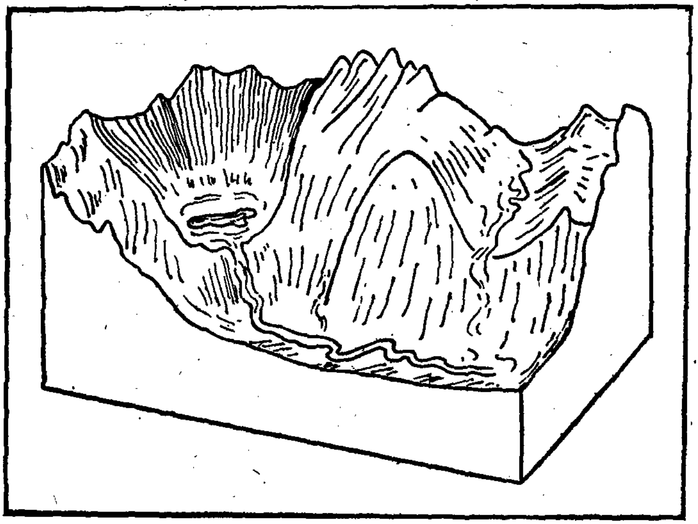

FIG. 19.1 Features of Glaciation—Cirque

the central floor and the opening is a gently elevated bed rock called **threshold.** Between the head wall and the threshold the basin is covered by a small lake called **cirque lake or tarn.**

The favourable conditions for the development of a cirque are as follows :

(*a*) Wide spacing of preglacial valleys so as to permit the expansion of the cirque.

(*b*) Sufficient amount of snowfall to form large snow fields and resulting glaciers.

(*c*) Fairly homogeneous rocks which permit equal extension of cirque in all directions.

Glacial Trough or 'U' shaped Valley

These are originally valleys formed by the running water. Once glaciers occupy these valleys, they start altering their cross profile as well as the long profile. After sometime the glacier alter them so much that they cannot be recognized as the original streamcut valleys.

The compact mass of ice in depth is capable of enforcing greater plucking action than the loose particles of ice on top. As a result, the floor and the bottom sides of the glaciated valley are subjected to greater erosion. So the originally formed 'V' shaped stream valley is converted into a broad-based and steep-sided 'U' shaped valley. The resultant feature is known as a **trough.**

The long profile of a river is almost a uniform curve unles there is an obstruction like waterfall. In the case of glacier, the moving ice does not change its course. It also removes the obstructions by plucking action which makes the surface of the valley very irregular in shape. The gentle slope may be followed by steep slopes. Such an arrangement appears like a staircase. The feature therefore is called a 'Glacial Stair Way.'

Hanging Valley

In the case of the river system the tributaries join the main river at the same level of flow. But in glaciated valleys or glacial

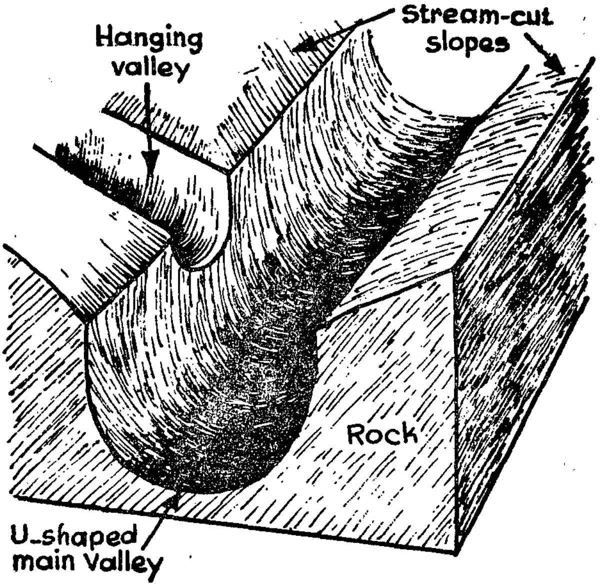

FIG. 19.2 Hanging Valley

troughs, the tributary valley does not join at the same level of the main valley. Instead, it is joining the main trough at a different level. This is mainly due to the differential erosion detween the main and tributary trough glaciers. When ice mass moves in the main valley, the glacier of the tributary valley remains stationary. Thus, the tributary valley is not eroded while the main valley is in action. In course of time the main valley becomes deeper and deeper while tributary valley remains at a much higher level. When ice melts the main glacial trough will leave a tributary joining at a higher level appearing like **a hanging valley.**

Truncated Spurs

In general glacial valleys are relatively straighter than the water eroded valleys. But at the same time glaciers start moving only in the valleys already carved by the river.

In the stream valley there are a number of spurs projected into the valley making the river take a winding course. When glaciers occupy the valley they try to erode the lower parts of the spur and make the course straight. The spurs, whose lower parts are eroded by glaciers leaving a steep slope, are called **truncated spurs.**

Fjords

These are glacial troughs eroded by ice mass below sea level. At the end of the Fjord submerged ridge is formed by the materials brought during the time of glacial deposition. If the water level goes down a small lake may be found between the coast and the ridge forming irregular coastal boundaries. Fjords are commonly found along the coast of New Zealand, Chile, Alaska, Greenland and Norway.

Landscape Formed by Continental Glaciation

The fine clayey soil brought by the glacier and washed down by the melt water of the ice cover an extensive area. The material is described as Glacial Till. The area covered by Glacial Till is known as 'Till Plain.'

When ice moves on the bed rock, it is able to make grooves and cut depressions are usually extended in the direction in which the glaciers move. They will be sufficiently deep and after melting

of ice they become lakes which are described as 'Finger lakes.' These finger lakes are found well formed in Scandinavia and parts of Canadian Shields.

The finger lakes gradually get silted up. In course of time these lakes may be completely covered by rich soil and provide rich agricultural regions. The finger lakes thus converted into plains are called 'Lacustrine Plains.'

Depositional Features of Glaciers

The frost shattering and plucking action of ice mass loosen free rocks from the steep slopes of the valley above the glaciers.

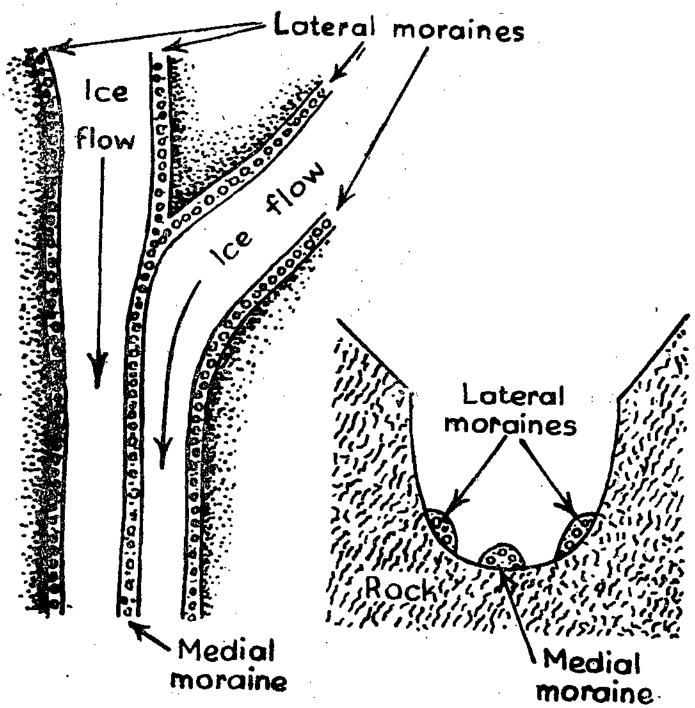

FIG. 19.3 Cross-section of Lateral and Medial Moraines

The resultant rock debris tumble down on the moving ice and form **moraines**.

Glaciers, while moving slowly downwards, carry these rock debris on their sides as long ribbons (Fig. 19.3). If the debris is on the sides of a glacier it is described as 'Lateral Moraines.'

When two glaciers of adjacent valleys coalesce, the inner moraines of each unite and form 'Medial Moraines' on the surface of the united glaciers (Fig. 19.3).

When a glacier advances in trough it drags the debris collected from the eroded glacial trough along its floor. The resultant moraine is called 'Terminal or End Moraine.'

Apart from these, when glaciers move in they pluck their floors. These plucked materials may be found in the inner portion of the glaciers and not at their end. If the lower part of the ice becomes heavily charged with these debris it cannot transport all. But the excess debris will get deposited on its ground surface and are described as **ground moraines.**

QUESTIONS

I. Short answer questions :

1. Explain plucking action.
2. What are the glacial deposits ?
3. What is meant by the term cirque ?
4. How are Fjords formed ?
5. A cirque is

    (*a*) Pyramidal Peak,
    (*b*) Glacial deposits.
    (*c*) Armchair like depression.
    (*d*) U-shaped valley.

6. Glaciers are

    (*a*) rivers found in the mountain regions.
    (*b*) moving masses of snow and ice.
    (*c*) waves produced along the shore.

7. Plucking is the process of erosion due to

    (*a*) wave
    (*b*) wind
    (*c*) river
    (*d*) glacier

8. Describe the snow line.

9. Describe the features of Cirque.

10. What are moraines ?

11. Differentiate tarns and finger lakes.

12. What is hanging valley ?

II. Long answer questions :

1. Discuss the salient features of the glaciated landscape due to mountain glaciers.

2. Critically examine the difference between the errosive work of a river and that of a glacier.

CHAPTER XX

WORK OF WINDS

The action of wind as an agent of erosion, transportation and deposition is familiar in places where loose surface material is presented without sufficient cover for stabilising the materials. The raising of cloud dust during dry season is also an adequate example for the wind action. In humid regions, except along the sea shore, wind erosion is prevented by a cover of grass and trees and the moisture-bound soil. But in dry areas, dust travels over long distances carrying enormous quantity of soil. It makes the sky dark and transforms the air into a suffocating blast. For example, the ships sailing in the Suez Canal collect plenty of dust blown off from the neighbouring deserts.

The wind can remove only dry and loose particles. The process of lowering the surface by removal of particles by the wind is called **deflation**; usually the wind is charged with sand particles. Near the ground the sand particles in the wind act as powerful scouring agent. This kind of erosion is otherwise known as **wind abrasion**. By constant abrative action, the sand particles get worn down by the action called attrition.

The wind carries larger particles for shorter distances but is capable of carrying finer particles over longer distances. The material, while in transport from one place to another, is made available for continuous weathering action. Wind blown deposits of fine clay soil are called loess. For example, in Northern China the loess soil derived from the central Asian desert is found over extensive areas.

As a result of wind action, three major types of surfaces are identified. They are:

(1) The rocky desert with a surface bed rocks kept dusted by abrasion is called Hammada.

(2) The stony desert with the surface covered by gravel or pebbles is called Reg or Serir.

(3) The sandy desert which is called Erg.

The effect of wind abrasion is clearly noticed in the forms of the Desert bed rock surfaces. The influence of a sand blast can be noticed clearly on cars driven across the desert. The paint is scoured off and the wind screen in the car appears foggy because of the blast action of the sandy wind. Similarly the exposed surface rocks are also affected. The softer rocks are eaily subjected to sand blast than the harder rocks. Due to these differential carvings of wind, variety of features like Yardangs, Zeugans may develop.

Yardang

Where there are thin alternative rock beds of soft and hard layers found, the soft material is quickly removed leaving back the harder materials, so that the hard rocks stand out distinctly. If the wind blows steadily in one direction over this kind of rock

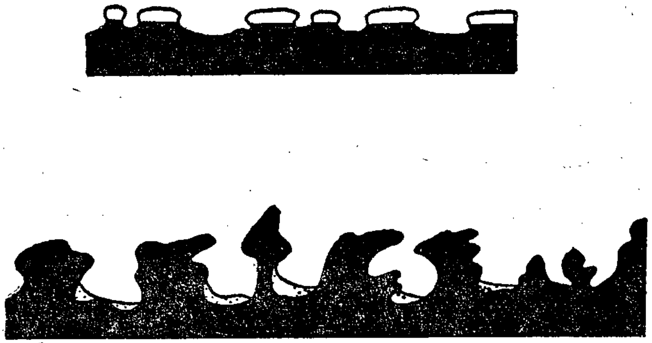

FIG. 20.1 Some Effects of Wind Erosion

layers the resultant feature will be a Cockscomb ridge, commonly known as **yardang**.

Zeugan

If the wind blown surface has relatively hard rock in the form of a sill then the resultant rock will form a flat top while the soft rock forming a depression at a distance The sill like rock will be broken alternatively forming the structure called zeugan,

Inselberg

The wind swept valley in Yardang and Zeugan will gradually become wider and wider. As a result. the outstanding resistant rock masses will appear with a narrow neck and broad top. Such residual structure of the resistant rock mass is called **inselberg** or isolated Hills.

Derikanter or Ventifacts

Sometimes small and large pieces of stones may be lying in the path of the wind in certain regions of the desert. If the wind blows almost constantly in one direction both the sides of those stone pieces get eroded. In course of time a change in the direction of wind may become the cause for the erosion of the other

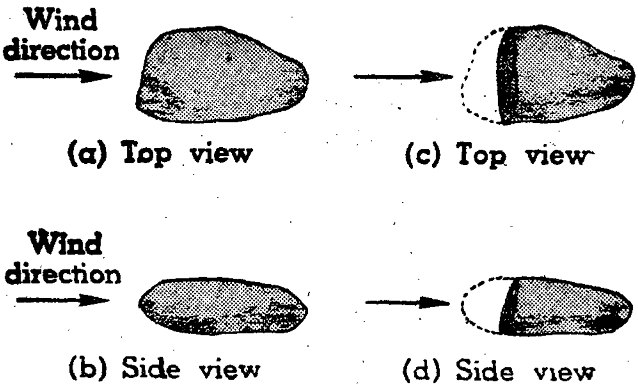

FIG. 20 2 Pebble Eroded to Form a Ventifact

side of the stone resulting into a triangular shape. Such triangular pieces of stones are called **derikanters** or **ventifacts**.

Wind Deposition

The deposition of the wind load results due to a decrease in wind velocity. Sand dunes and Barkhans are some of the prominent depositional features of the wind.

Sand Dumes

When a rise in the ground or the presence of the vegetative cover is found in the path of the wind, the force of the wind is checked. Therefore, wind drops its load of sand, forming a sand ridge with a definite summit. The resultant feature is called a

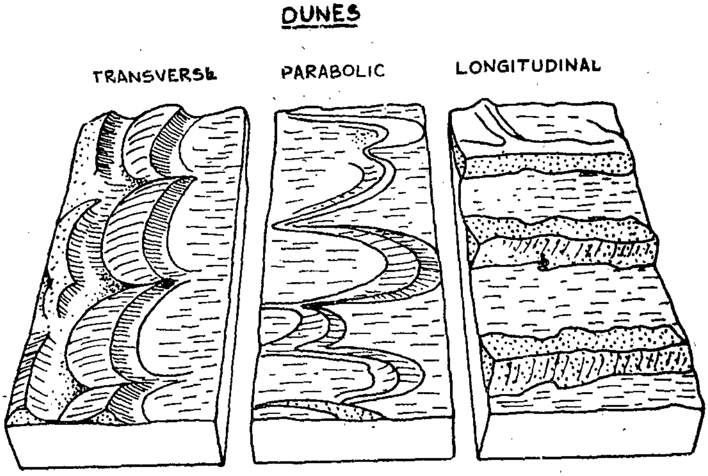

FIG. 20.3 Dunes

sand dune. The size of the dune varies from a few metres to 150 metres and even to 300 metres in some deserts. The dunes that are formed in the direction opposite to the wind are called **transverse dunes.** If the dunes grow in the direction parallel to the wind are called **parallel dunes.** Examples of these dunes are found in the Rajasthan desert.

Barkhans or Crescentic Dunes

While sand dunes migrate, the less resistent extreme portions of the dunes move more readily with the wind and then heavy summits of the dunes in the middle are left behind. The resultant crescentic shaped sand dunes are called **barkhans.** Sometimes the height of a barkhan reaches nearly 30 metres in its centre,

QUESTIONS

I. Short answer questions :

1. Explain the term deflation.
2. What is loess? What are the important loess areas of the world?
3. What are Pediments?
4. Name different types of sand dunes.
5. Describe the abrasive work undertaken by winds.
6. Define the terms Yardang and Zeugan.
7. What are the Seif dunes?
8. Differentiate the terms deflation and abrasion.
9. What is a transverse dune?

II. Long answer questions :

1. Explain the role of wind in changing the desert landscape.
2. Give an account of desert landscape features and the related wind action.

CHAPTER XXI

WORK OF WAVES

The friction and pressure exerted by surface of the water causes waves. Wave, when it approaches the foreshore water, becomes a breaker. It operates as an agent of erosion in all the four different ways namely corrosion, abration, attrition and hydraulic action.

The wave breaker, when it hits upon an obstruction exerts a greater amount of pressure and thus erodes vigorously. In rocks with jointing and bedding along the coast wave erosion is more effective. Here wave acts as a quarrying agent on the rock surface. The effect of wave action can be seen on the coast near Mahabalipuram in Tamil Naidu.

Wave action against the slope of coastal rock surface results in the formation of cliffs. By constant collapse of the rock bed at the base, the cliff recedes presenting a steep face towards the advancing sea. If the rock bed is poorly consolidated the cliffs will be protected by fallen debris. Coasts with hard and weak resistant rock masses wear back irregularly. The hard rock mass projecting towards sea is called **head land** and the adjacent highly eroded depression is called Bay.

In some places, where the belt of weak rock beds is found in between hard beds, wave vigorously and easily erodes the weak rock and excavates caves. The cave roof may collapse due to subsequent removal of rock debris and long narrow inlets may be formed.

If two caves on opposite sides get united with their persistent hard rock, a natural arch is formed. It is also known as 'Natural bridge.' The subsequent collapse of the feature results in the formation of isolated-Stack.

Cliffs recede back due to constant wave cutting and leave a wave-cut platform in front of it. A wave-cut platform gets widened when the rate of coast erosion is reduced. Just as in the

case of cliffs, the front of the platforms with poorly consolidated rocks get abraded quickly and coast erosion proceeds vigorously. The upper part of the platform will be visible as the rocky fore-shore is exposed at low tide.

Marine Deposition

As the waves lose energy the loose sediments from the sea floor is driven landwards by waves and currents. The materials

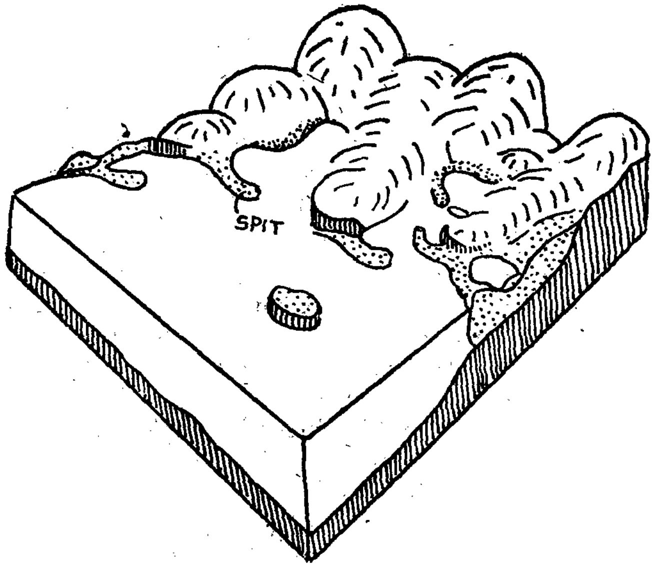

FIG. 21.1 Marine Erosional Features

get deposited long before they reach the shore. These deposits modify the coast line forming different marine features like beaches, spits, bars, etc.

The formation of beaches is due to the temporary deposition of sand, gravel and pebbles accumulated on the shore in between the low tide level and the coast line. If the wave action is low, the growth of beach is prominent. Marina beach in Madras is one of the prominent examples. Sometimes the stormy wave may destroy the beach itself.

When the headland and bay occur alternatively the waves and currents may deposit the materials tangentially to the headland. These deposits may be attached to the land at one end while the other end terminates in the open sea. With the result **Spits** are formed as sediment embankments.

Sometimes the development of submarine deposits run parallel to the shore line. Due to constant accumulation of the deposits these formations rise above the water level. The resultant formation is called an **offshore bar.** As these offshore bars grow the wave breakers sweep them at certain level. Materials are then transferred from the outer to the inner side towards the shore.

An offshore bar, when it reaches an outward bulge of the coast, begins to construct an ordinary beach enclosing a lake

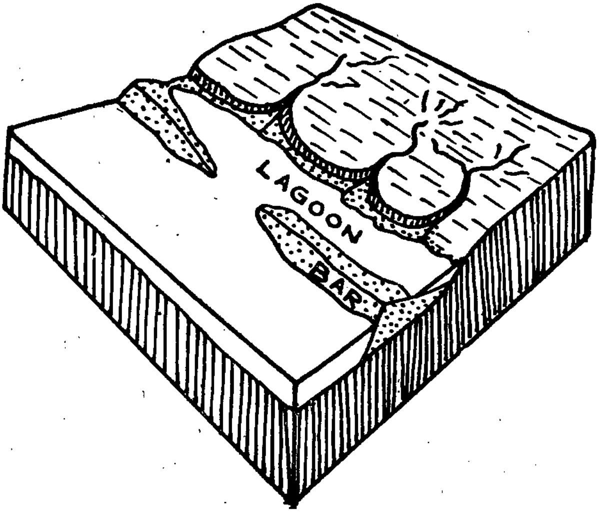

FIG. 2.12 Offshore Bars and Lagoon

known as '**lagoon**.' It is usually connected with the open sea by a narrow gap between the bars and headland coast. The Pulicat lake on the east coast and Vembanad lake on the west coast in Kerala are notable examples of lagoons in South India.

QUESTIONS

I. Short answer questions :

1. What are lagoons ?
2. Define shore line of emergence ?
3. What is a spit ?
4. Name the features produced as a result of marine erosion.
5. What is a cliff ?
6. Explain headland and bay.

II. Long answer questions :

1. Describe the work of the waves as agents of erosion.
2. What are the characteristic features of emergent coast ?

CHAPTER XXII

WORK OF UNDERGROUND WATER

Solution is one of the dominant processes in the formation of certain landscape features This process of erosion as an agent of gradation is particularly very significant in Limestone and Dolomite regions. The resultant landscape is known as Karst Topography. The very word itself comes from the narrow strip of Limestone region along Adriatic Coast in Yugoslavia. The development of this type of landscape is also found in the Karst regions of France, Spain, Greece and coastal fringes of the Great Australian Bight. In U.S.A. Karst regions include Central Florida, Great Valley of Virginia, Tennessee, Southern Indiana and Kentucky.

For the development of Karst landscape four major conditions are essential:

(1) The region should consist of limestone bed rock formation.

(2) The soluble rock should be highly jointed and in thin beds.

(3) Trenched major valleys should have soluble and welljointed bed rocks.

(4) The region should receive a moderate amount of rainfall. Since solution work will be limited in areas with less rainfall, the karst features cannot develop so well as they do in regions of moderate rainfall.

Karst Landscape Features

Terra Rossa

Descending ground water may dissolve certain parts of rocks which are soluble. It leaves behind insoluble materials as residue. The residual materials are red and clayey soils extending into open

joints. On steep slopes such materials may be washed away while these materials may remain in varying thickness on gentle and moderate slopes. These deposits appear like the laterite soil of the tropics. This type of soil is called **terra rossa.**

Lapies

When the slope is very steep, the surface remains barren. The surface of the rock may be etched, flouted and grooved. Such a rough surface is called 'Lapies.' The development of lapies will depend upon the composition of rock texture, structure and maturity of the slope. This does not commonly occur in horizontal rock surfaces.

Sink Hole

It is a funnel shaped depression, broader near the surface with narrow passage. It has an average depth of three to ten metres. There are two types of sink holes depending on their mode of formation. They are :

(1) The sink holes that are developed slowly downwards by solution beneath the soil mantle without disturbing the rocks.

(2) The sink holes that are produced by collapse of rock above an underground passage.

Doline or Swallow Hole

The sink hole formed due to solution is also called doline in Yugoslavia. Sometimes surface water may drain into the doline and even penetrate deep into the earth by slow percolation. Thus the doline literally swallows the run off and therefore is called a **swallow hole.**

Sink Hole Ponds or Karst Lake

While the water is percolating, fine clayey soil may get deposited slowly in the passage and thus obstruct the free flow of water. Then the neck and the broad top may be filled with water forming a small lake. Such lakes are called Sink hole ponds or Karst Lake. It is commonly found in Florida State of U.S.A.

Uvalas

Sink holes may expand in diameter and as a result they unite to form a compound sink hole. Sometimes these may be developed

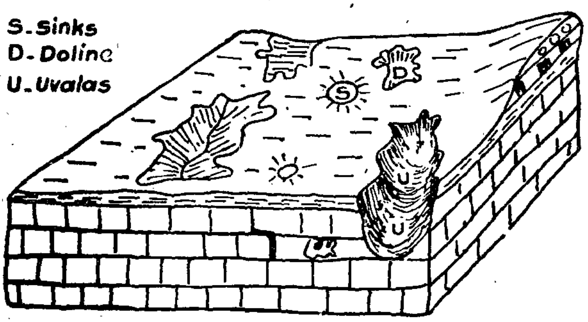

FIG. 22.1 Sink holes and Uvalas

from the surface to join the passage already made under. This leads to collapse of a certain part of roof resulting in the formation of large depressions called 'Uvalas.'

Polje

Very large structure of uvalas extending for miles with narrow and deep depressions are called **polje**. The largest polje is about 40 miles long and three to seven miles broad. They are mainly found along fault line.

Blind Valley

In some cases the sink holes may become large enough to permit rain water of the stream to flow through it. As a result the intermittent dry bed of the channel will be obscured and gradually lose all the characteristics of a valley. Then it is called a **Blind Valley**.

Natural Tunnel and Bridges

When the subterranian passage is along the sloping surface, the stream flowing under the surface may emerge through an opening. Such a structure is called **Natural Tunnel**. The roof of the tunnel may collapse due to continuous solution activities. In course of

time the roof reduces into a very small bridge. It is called **Natural Bridge** or a **Karst Bridge.**

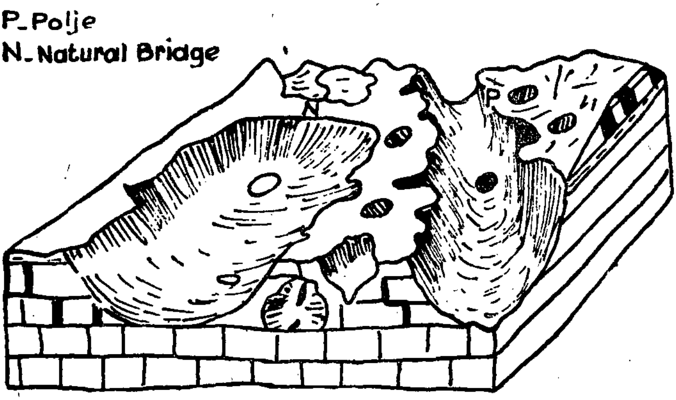

FIG. 22.2 Karst Bridge and Polje

Caves or Caverns

In the case of a tunnel the two ends are open almost to the same extent. But if there is only one end opened while the other is closed it is called **cave or cavern.** Water may seep through the rocks and flow from the cave. Sometimes it may be dry too.

Stalactites and Stalagmites

In some cases, the slow seepage of lime-charged water from the roofs and walls of these caves lead the formation of calcium carbonate deposits. These deposits are called **Stalactites,** if they grow downwards from the roof of the cave, and **Stalagmites,** if the deposits grow upward from the floor of the cave.

QUESTIONS

I. Short answer questions :

1. What are sink holes ?
2. What are Stalactites and Stalagmites ?
3. What is a blind valley ?
4. Distinguish uvalas and polje.
5. Name two important karst regions of the world.

II. Long answer question :

Illustrate karst landscape with suitable examples.

CHAPTER XXIII

CYCLE OF EROSION

A landscape has a definite life-history of evolution. During its evolution it shows a series of gradual changes, whereby the initial (a high relief) forms pass through a series of sequential forms (different intermediate forms) to an ultimate (peneplain) form. These can be broadly grouped into three major stages as Youth, Maturity and Old stage. From its origin to evolution the topography produced by streams has had a cyclic development. The cycle of erosion can be simply explained by the reducing of newly uplifted seafloor to a final production of another surface of low relief. The recognition of the possibility of such eventual change of relief is the first and the most fundamental principle of the Cycle of Erosion.

The cycle of erosion is defined the *time* required for streams to reduce a newly uplifted land mass to base level. The geomorphic cycle is the topography developed during the various stages of a Cycle of Erosion.

The evolution of the landscape involves three important factors such as structure, process and stage. The stage describes about the evolution obtained in the landscape development; process says about the Sculpture and character of the country while the structure explains about the rock characteristics.

The normal cycle of erosion can be best illustrated by the normal river action. The conception of the Cycle may be extended in some measure to cover the cases of 'arid' and 'glacial erosion'. The initial surface which forms the starting point of a cycle of erosion may be of very varied forms and structures. The simplest case considered here is the uplift of a new land from beneath the sea. Assuming that the uplift is so rapid, that there is no time for any significant amount of erosion during its progress; the deformation during uplift produces a new land surface. The deformation of the relief is revealed by the first streams of inequalities. Their causes will be primarily, conse-

quent upon the broader, original slopes of the surface. These are called as *Consequent Streams* which altogether from a series of consequent valleys during the first stage of cycle of erosion.

The interstream areas or interfluves will at first be broad flattopped ridges. These ridges retain extensive tracts of the initial surface on their summits. The progress of valley-widening narrows the interfluves and it continues its activity till the down cutting has stopped. This finally results in the destruction of the last surviving traces of the initial surface. This is a critical point in the development of the relief.

The rapidity of the youth stage to mature stage clearly depends in part on the texture of the drainage, i.e. the closeness of spacing of the streams. The extent of the tributary development will depend on the amount of the rainfall and the perviousness of the rocks.

The attainment of nature dissection need not necessarily coincide with the first maturity, or grading of the drainage system. The aspect of a mature landscape is, however considerably affected by the quantity and arrangement of the disintegrated rock-waste which covers the slopes. In youth, the rock-waste is removed rapidly, owing to the steepness of the valley. The slopes have *Scree* beneath it and the slopes are in fact ungraded. In later stages slopes become *gentler* and they become entirely covered with a mantle of fire-grained waste. This is in a state of constant, though slow, transit, downhill, under the influence of soil creep or *Solifluction*. The grading process eventually results in the transformation of sharp divides into a rounded or convex form. The process is effective under moderate conditions of rainfall.

In the later stages of the cycle, lateral corrosion, followed by deposition. Supervenes in the valleys, while the rounded divides developed in middle or late maturity undergo continued reduction. The maturity stage thus passes by insensible gradation into old stage, with the production of a surface of generally low relief.

The Cycle Concept

The basic ideas of the Cycle of erosion took their origin in the work of Powell, Gilbert and others. They were well adopted

to evoke a realization of the fundamental laws of water-erosion. The systematic presentation of the scheme of the cycle was the work of W. M. Davies.

Cycle of Erosion and the Formation of Different Earth Features in Different Stages

The cycle of erosion explains that the uplift is much greater than the rate of erosion. The topography will at first be youthful; gradually it will attain maturity; finally as the relief is diminished and base level is approached, the land surfaces will become old. The length of the cycle of erosion mainly depends upon the following factors such as structure of the landmass, composition and distance from the sea and the amount of rainfall.

Youthful Stage

The youthful topography is characterised by comparatively few streams, and the drainage may be poor with lakes and swamps on the divides between the streams. Divides are wide and may be high. The streams flow in steep walled canyons, gorges or 'V' shaped valleys; waterfalls and rapids are numerous. During this stage, the streams are actively engaged in cutting their valleys deeper. The important features produced during this stage are canyons and Gorges, and waterfalls and rapids, etc.

Mature Stage

Many changes have taken place during the course of attainment of a region from youth to matute stage. Drainage is better developed with a number of streams draining the region. The main streams have cut their valleys to base level. Tributaries are well established. Lakes, swamps, waterfalls and rapids have largely disappeared. The lateral erosion result in the formation of valley flats. Divides and narrow-hills and ridges are reduced to a low level with moderate slope.

A marked difference is found in the patterns of drainage developed (*a*) in regions of homogeneous rocks without important structural features and (*b*) in folded heterogeneous rocks. The steep cliffs of massive resistant sand stones or lime stones which are so characteristic of Youthful topography largely disappear and tend to form broad sweeping curves of well matured regions,

Old Stage

The typical old topographic regions reveal the following features :

All the mainstreams are graded and are meandering back and forth over their flood-plains. Their currents are slow and their carrying power is limited. The divides between the streams are low and narrow. The whole landscape is subdued. It may be gently rolling or monotonously flat. The remnants of erosion stand above the gentle slopes of the land and the low gradients of the streams, putforth that mechanical erosion is very slow. The streams tend to form flood plains across uplifted beds of varying importance.

An interruption in any stage of the Cycle of erosion may be termed as rejuvenation. This is caused by sudden uplift caused by continental or mountain-building movements, lowering of outlets and lowering of sea level.

QUESTIONS

I. Short answer questions :

1. What are three stages in the concept of cycle of erosion ?
2. What is fundamental principle of cycle of erosion ?
3. Define 'consequent streams.'
4. Mention the different features formed in different stages.
5. What is rejuvenation ?

II. Long answer questions :

1. Explain the concept of erosion and bring out the different earth features formed in different stages.
2. What are the major differences between stages in the evolution of different earth features ?

CHAPTER XXIV

TROPICAL LANDFORMS

The tropics are the zone of the earth that lies between the Tropic of Cancer and the Tropic of Capricorn. In general, they are characterised by high temperatures. Although the rainfall has common characteristics throughout the Tropics, there are great differences which are at the origin of the subdivisions of this climatic zone. Tropical rains are produced by convection. They are generally accompanied by lightning and thunder The high temperature is partly responsible for the nature of the rainfall. The evaporation in the tropics increases appreciably with temperature because of the rapid rise in the water vapour capacity of the air. The influence of temperature, combined with that of humidity, is reflected in the decomposition (mineralisation) of organic matter so important in pedogenesis, weathering and the elementary forms of surface drainage.

Landforms of the Tropical Zone

Savigear (1965) defined that, 'a landform' is a feature of the earth's surface with distinctive form characters which can be attributed to the dominance of particular processes or particular structures in the course of its development and to which the feature can be closely related. The most obvious landform found almost everywhere is the river valley. Less not clear are the discrete forms of the land surface; individual hills and units of slope. These fall naturally into three groups; those developed over the weathered mantle, those formed from solid rock and slopes developed over transported materials. The rocky inselbergs of the tropical shields possess a considerable variety of surface materials, and the controversial 'pediment' landform may also be underlined by regolith, rock or alluvium. Escarpments occupy a central position and although they have much in common with the marginal slopes of residual hills.

Residual Hills of Tropical Landscapes

A prominent feature of the tropical landscapes are inselbergs. These are often referred as isolated hills rise steeply from plains, like islands from the Sea. The term 'inselberg' appears to have been proposed by Bornhardt in 1900, to describe the abrupt and rocky hills that commonly interrupt tropical plains. It is also described as steep-sided residual hill. Later the inselbergs may therefore be taken to include hills of sedimentary rock, residuals of *saprolite capped by indurated laterite* and hills of crystalline rock which vary from tors or 'boulder inselbergs' (Birot, 1968) and angular castellated forms or 'Kopjes' (or Koppies) to the marine rock domes The distinction between tors and domes is usually made in terms of the marked spheroidal form and generally smaller size of the former. The domes and tors which do not occur strictly as inselbergs commonly form parts of escarpments which altogether form major features of the many landscapes of the tropical shields. It can be also pointed out that outside of the tectonically active zones certain recurrent features of the tropical terrains may be described in terms of characteristic Valley forms and residual hills.

Residual Hills of Karst Landscapes

Some distinctive forms of the Tropics are particularly associated with limestone or Karstic terrain. Residual Karst inselberg are common in humid tropical limestone regions, and are characterised by steep, sometimes vertical sides which may be ease-hardened by redeposited crystalline calcium carbonate. Such hills may represent limestone residuals standing above plains and relatively on permeable rock. Such hills are given a variety of local names. The smaller ones are often termed *hums* and very large residuals are called mogotes. Solutional weathering is the dominant process responsible for the formation of the above and they are largely confined to the more humid regions of the tropics and sub-tropics.

Types of Tropical Terrain

The identification of certain distinctive types of terrain are based on the simple morphometry than on the pattern of occurrence of particular surface materials and landforms developed on them.

Tropical Relief Types in Tamilnadu (Madras)

Budel (1965) recognized three basic relief types such as (1) Tropical plain relief (2) Tropical mountain relief and (3) Tropical ridge relief.

1. *Tropical Plain Relief*

It is exemplified by the Tamilnadu plain which rises from sea level to about 100 m inland. The characteristic feature of this landscape is the distribution of isolated high inselbergs bordered by narrow *radial* pediments. Above a dissected escarpment zone, a similar plain, the Bangalore plain is preserved at an altitude of 750—900 metres.

2. *Tropical Mountain Relief*

This forms the inner border of Tamilnadu plain. It is characterised by frequent inselbergs or groups of hills leading towards an escarpment dissected by deep, narrow valleys.

3. *Tropical Ridge Relief*

It appears above the escarpment, and merges into the Bangalore plain. It consists of narrow groove-like valleys etched into the upland surface by selective weathering and concentrated slopewash.

QUESTIONS

I. Short answer questions:

1. What are the essential climatic characteristics of a tropical region ?
2. Mention the important earth features found in the tropical landscape.
3. Define 'Inselberg'.

II. Long answer questions:

1. Attempt a division of landscapes in the tropical region, with a special reference to Tamilnadu.
2. Describe the landforms of the tropical zone.

CHAPTER XXV

SOIL

Soil is the most important natural resource available for man. He gets all his requirements such as food, clothing and shelter either directly or indirectly, from soil. Further soil constitutes a major geographic factor. Hence, the study of soils has gained paramount importance in the recent years. The systematic study of soils is known as 'Pedology'. The renounced Russian Soil Scientist (Pedologist) was Glinka. The country which has recognised the importance of this science is the Union of Soviet Socialist Republic.

Soil to a layman is 'the dirt' on the surface of the earth. To a soil scientist or Pedologist, the word soil conveys a somewhat different meaning, but no generally accepted definition exists. However, soil can be defined as 'a natural body composed of minerals and organic constituents. They are usually unconsolidated and of variable depths. They differ from the parent material in morphology, in terms of physical, chemical and biological characteristics'. The physical, chemical and biological qualities support plant growth.

The soil portion of soil is both inorganic and organic. Weathering of rock produces the inorganic particles, which give the soil the main part of its weight and volume. These particles vary in size from microscopic to large gravel. The organic solids consist of both living and decayed plants and animals, such as roots, fungi, bacteria, worms, insects, etc.

Physical and Chemical Properties of Soil

Soil colour though a minor factor itself is perhaps the obvious characteristic that is first noticed. From the colour it can be inferred how a soil is formed and what it is made of. Soil horizons are usually distinguishable by colour difference. Depending upon the amount of humus content the colour ranges, from white to black. The proportion of humus in the soil depends

upon the luxuriance of vegetation and intensity of microbial activity. The microbial activity in turn depends on climate. The presence of iron oxide gives rise to red colour whereas the hydrated iron oxide gives yellow colour to the soil. Red colour generally indicates that the soil is well drained.

Soil texture is a major characteristic of the soil. It refers to the particle sizes composing the soils. Particles are classified as various grades of gravels, sand, silt and clay in decreasing order as shown below :

Soil Texture

Name			Diameter in mm.
Coarse gravel	—	—	Above 2
Fine gravel	—	—	1—2
Coarse sand	—	—	0.5—1
Medium sand	—	—	0.25—0.5
Fine sand	—	—	0.10—0.25
Very fine sand	—	—	0.05—0.10
Silt	—	—	0.002—0.05
Clay	—	—	Below 0.002

The standard definition of soil-texture classes in which the proportion of sand, silt and clay is given in percentages. For example, sandy loam consists of 65% of sand, 20% of silt and 15% of clay. In the case of clay loam it is composed of $33\frac{1}{3}$% of sand, $33\frac{1}{3}$% of clay and $33\frac{1}{3}$% of silt. Various soil texture classes and the proportion of silt, clay and sand are shown in Fig. 25.1.

Soil texture is important because it largely determines the water retention and transmission properties of the soil. Sand may drain rapidly whereas in clay it is very slow.

Colloid particles are very small in size i.e 0.002 mm. These finely divided particles can be divided into humus colloids and organic colloids. Colloids have the property of being electrically charged. Therefore they attract and hold ion which are the unit

chemical particles of dissolved substances. Positively charged ions of calcium, magnesium and potassium are known as bases. The process of providing these bases by colloids to the plants is known as base exchange. The positively charged hydrogen ion in soil solution makes for acid condition. The concentration of

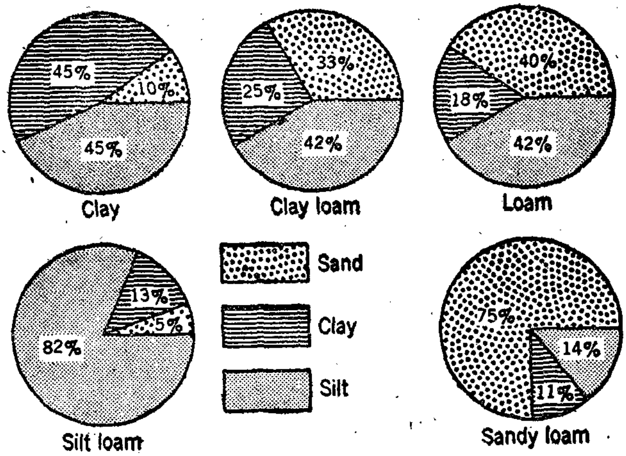

FIG. 25.1 Soil Texture

hydrogen ion in the soil solution, relative to negatively charged hydrogen ions is known as the pH of the soil. The amount of pH in the soil is the measure of soil, alkalinity or acidity. In soils, a value of 7 in the pH scale is neutral, whereas below 7 (4—7) in acid soils but above 7 (7—10) in alkaline soils.

The term soil texture refers to the way in which the soil grains are assembled. Soil structure is very important because they influence the rate at which water is absorbed by the soil, the susceptibility of the soil to erosion, and the ease of soil cultivation. On the basis of structure soils can be classified as blocky, granular, prismatic and platy. Irregular pieces with sharp corners and edges give rise to blocky structure. More or less spherical pieces of grains make granular and current structure. Some soils are made up of columns or prisms and they are called as Columnar or prismatic structure. Platy soil structure consists of plates in a horizontal position.

Soil air is an another constituent of the soil which occupies the pore spaces when it is not saturated with water. The soil air contains excess of carbon dioxide, but a deficiency of oxygen and nitrogen.

Soil water, one of the soil constituents, is a complex chemical solution of such substances as bicarbonates, sulphates, chlorides, nitrates, phosphates, and silicates of calcium, magnesium potassium, sodium and iron.

Soil Profile

When a vertical section is made through a soil it is found that a series of distinct layers or horizons may be recognised which

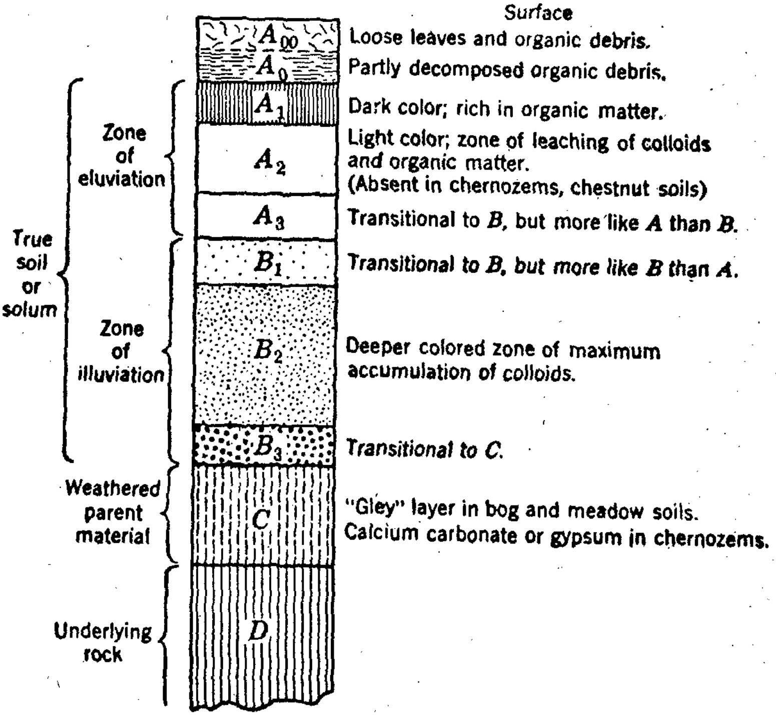

FIG. 25.2 Soil Profile

differ in their chemical and physical properties. Soil profile refers to the arrangement of the soil into layer like horizons of differing

exture, colour and consistency. Soils are recognized and classified into broad groups on the basis of the parts of the profile that are present. Basically there are three parts in the soil profile. They are (1) the true soil or solum, (2) the sub-soil and (3) the bed horizons A and B represent the true soil, horizon C is the sub-soil or weathered parent body. It is designated as D horizon. The horizon or group horizons lies immediately below the landscape. This is often described as the eluvial (washed out) horizon. Because, it commonly has had material removed from it and carried down into the B horizon. Maximum biological activity is found in the A horizon. The horizon B is designated as the illuvial (washed in) horizon. Because the materials removed from the A horizon, such as iron, aluminium and clay are found concentrated here. The C horizon consists of weathered material which has not yet been subjected to soil building processes. In some cases the C horizon may be very thin or even lacking. This is because, the soil building processes have followed closely upon the weathering processes. A soil profile developed through two types of parent material is known as composite profile.

Soil Forming Factors

Many processes and influences act together to develop a soil. This is altogether known as Soil Formers. There are five principal factors in soil formation processes such as the parent material, climate, topography (land forms), biological activity and time.

Parent material includes the texture and structure of the material as well as its mineralogic and chemical composition. The soils were commonly divided into two major groups, residual and transported. Residual soils were classified according to the type of rock from which they were derived. Thus limestone soils, sandstone soils, gravelly soil, granite soils and other soils were recognized. Transported soils were classified as glacial, alluvial, colluvial, colian, lacustine and marine according to the way in which the materials were deposited.

Climate is the most active soil forming factor. Climatic elements involved in soil development are moisture conditions affecting the soil (Precipitation, evaporation and humidity), temperature and winds. Precipitation provides the soil water

which activises chemical and biological activities. For example, in wet equatorial rain forest belt the soils are deficient in silica as well as in bases and they result in low fertility.

Topography profoundly affects the character of the soil profile. On steep slopes, the profile may never become mature because erosion removes weathering products as rapidly as they are formed. Topography also influences the configuration and position of water table and circulation of water through the soil.

Probably the least appreciated factor in the soil formation is the role played by organism. Many pedologists believe that the pedoganic processes do not begin until there is an introduction of biotic agencies into the interaction between parent material and environment.

Soils that develop under similar climatic conditions are called as **zonal soil**. Soils that show the effect of local conditions rather than broad climatic controls are designated as intrazonal soils. Soils which lack definite profiles are termed as zonal soils. Stream alluvium, dry sands and colluvium are examples for a zonal soils.

Major Soil Groups and their Distribution

Soil zones are identified on the basis of the climatic conditions and vegetation. However, there are nine major soil groups in the world.

(1) Tundra Soils

These soils develop at high altitude under Tundra vegetation. These soils have dark brown peaty layers at the surface, over grayish horizons. Often parent material underneath is permanently frozen. Hence the profile is shallow and much of the undercomposed organic material is found at the surface.*

(2) Pedozols

Pedozols soils show well developed A, B and C horizons. The surface material is made of organic matter under which it is whitish or greyish. Below this layer is a zone in which iron and alluvium

* Fig. 25.3—See at the end of the book.

minerals accumulate. The layers A and B are strongly acidic in nature. These soils develop under coniferous and mixed hard wood forests. This type of regions is of cold and moist climates.

(3) Grey-brown Podzolic

The arrangement of layers is essentially the same as in the pedozols, but the soil is not so acidic. The top layer is thicker and contains more humus. The humus is well decayed as a result of bacterial activity and is less leached. These soils develop under deciduous and mixed deciduous—Coniferous forest in areas of moist climate with a cool to cold winter.

(4) Yellow and Red Soils

These soils have a rather thin layer containing organic materials. This layer rests upon a yellowish brown leached horizon. This layer is underlined by deep red or yellowish layer. The reddish soils were developed primarily under deciduous forest and the yellow soils under coniferous forests, in areas of moist and warm climate of the lower middle latitudes.

(5) Laterite Soils

Due to vigorous bacterial activity, these soils have little organic materials in the top layer and it is well decayed. Leaching has affected not only the plant salts and the lime but also removed parts of the silicates. The upper layers have less of silica content but rich in aluminium and iron hydroxides. These soils are found in humid tropical regions.

(6) Prairie Soils

These are deep, very dark brown soils. They exhibit a lighter colour at a depth of three to five feet, where they grade into lighter coloured parent material. These soils develop under the tall grass prairies of the middle latitudes where not too humid conditions prevail. These soils are neutral in reaction and of high fertility.

(7) Chernozomes

These soils have a very dark brown, almost black top layer. This layer is underlined by a light coloured layer rich in lime.

They develop under tall grass prairie of sub-humid regions in the middle latitudes. Their fertility is high.

(8) Chestnut and Brown Soils

There are dark brown to brown soils decreasing in thickness as the colour becomes lighter. The dark brown layer is underlined by a whitish horizon rich in lime. These soils are typical for steppe regions in the middle latitudes. The fertility of this soil is high.

(9) Sierozems and Desert Soils

These soils are greyish and low in organic matter. A highly calcareous horizon often lies close under the surface. The Sierozems are found in the continental deserts and the fertility is from medium to high.

A soil catena consists of a sequence of soil profiles whose characteristics were determined mainly by varying topographic and drainage conditions under which they formed.

A paleo soil is an ancient soil that developed upon a former landscape. Three types of paleo soils are recognized. They are the relict, buried and exhumed soils.

The removal of soil either naturally or as a result of human action is called **soil erosion**. Water, wind, ice are the important soil eroding agents. Water is the most important agent of erosion and it takes place in the form of gully erosion and sheet erosion. Wind erosion is common in the dry arid regions. Erosion by glacier is pronounced in polar and at high altitudes.

Soil conservation is the measure taken to prevent soil erosion. There are a number of soil conservation practices such as crop rotation, contour forming, strip cropping, terrace cultivation and development of permanent pastures.

QUESTIONS

I. Short answer questions :

1. Define soil.
2. What is soil texture ?

3. Describe soil texture.

4. Give examples for transported soils.

5. Residual soil—Explain.

6. Explain eluvial and illuvial soils.

7. Define soil profile.

8. Soil Erosion—Explain.

9. Why soil conservation is important?

II. Long answer questions :

1. Describe the soil forming factors.

2. Describe the major soil groups of the world and account their distribution.

CHAPTER XXVI

HYDROLOGY

Water resource is the most important resource of the world. The life on the earth's surface cannot exist but for the availability of water. Both the animal kingdom and the vegetable kingdom depend upon water for their survival. According to the human physiology the water forms the major constituent of the human body. The young people below 15 years have 90% of their weight in the form of water whereas it comes down to 75% in the old people, about 50 years.

The water which helps human society as a friend in a variety of ways also becomes adversary to them. The river which irrigates thousands of hectares of land may also submerge the same during floods. Similarly, the water without which no man can live on the earth for more than 72 hours, also can become fatal or harmful to him when it carries the germs of epidemic diseases like cholera, typhoid, jaundice, etc.

About 71% of the total earth's surface is covered with water yet it is frequently scarce. The water controls almost all of human activities such as agriculture, industry, forestry and fishing. The territorial or international waters involve the politics in terms of deciding the limits for fishing and defence purpose Governments of adjoining countries also. For example the present discussion on the 'peace zone' in the Indian Ocean region. The importance of water in the present situation forced to develop a systematic study on it and thus the subject 'Hydrology' emerged. The rapid growth of world population and the speed with which water gets polluted due to industrialisation encouraged the rapid development of Hydrology in the recent years.

World Water Resources

About 97% of the total earth's water is found in the oceans which cover 71% of the earth surface. Only 3% of the total

earth's water is distributed over the land areas which accounts for 29% of the earth surface. The ice sheets and glaciers found in the middle or high latitudes lock up with them about 75% of the world's total fresh water. The remaining 25% (a little less) is stored in the underground as ground water storage. The rivers and lakes have also 33% of the world's fresh water in them.

Hydrological Cycle

The processes of exchange of water from the earth to the atmosphere and vice versa is the main theme of study for the

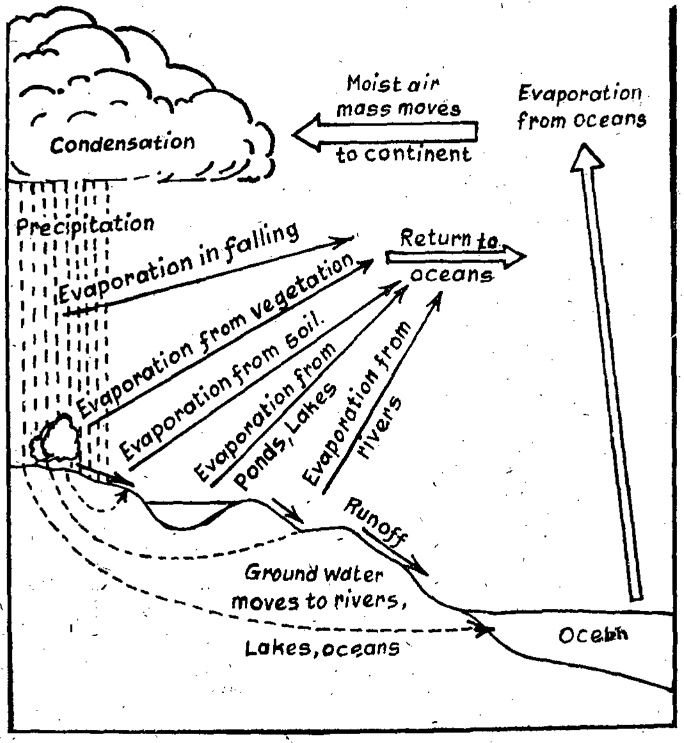

FIG. 26.1 Hydrological Cyclone

beginners of hydrology. In the process of exchange of water from earth to the atmosphere and back so many stages are undergone in the hydrological cycle. They are evaporation, condensation,

formation of clouds, precipitation, run off and underground water.

Water is a dynamic resource of the world, in the sense that it is a mobile one, both physically and geographically. The water changes its form from liquid to gaseous or solid state or vice versa physically. Similarly rivers and the ocean currents take the water from one geographical region to another. The river Ganga for example rises in the Himalayas, a mountainous region and then it runs down through the plains and enters the sea after flowing through Bangladesh. Similarly the tropical water mixes with that of middle latitudes and poles because of ocean currents like Labrador currents, Gulf stream, etc.

The water is evaporated from the surface of the oceans and the land, because of the solar energy. In the processes of evaporation the liquid water transforms itself into a gaseous stage, as water vapour. This water vapour has been carried to the atmosphere by the wind. When the air in the atmosphere gets saturated with the water moisture, it cannot hold any more addition of water vapour. Once this state is reached the condensation of water moisture takes place in the atmosphere. Thus the condensed water vapour fall through the atmosphere in the form of precipitation.

A part of precipitation over land is intercepted by the thick vegetations, which cover the earth surface. The remaining precipitation falls directly on the surface of the earth. Some water which falls directly on the earth surface and the water intercepted by the vegetation is returned to the atmosphere due to evaporation. The soil absorbs some amount of water and retain with it. This is known as the **soil moisture**. A portion of water seeps however through the various rock stratas and thus the ground water storage is built up. The vegetations in the process of absorbing the nutrition from soil takes some quantity of water from the soil through their roots. The vegetations during the phytosynthesis activity allows the water from the plant to get evaporated from the surface of the leaves. This process by which the water escapes from the vegetation is known as **transpiration**.

The water which is still left on the surface of the earth after the infiltration and evaporation and absorption by the plant runs

as streams and rivers and finally reaches the ocean. However some water is retained wherever small depressions are found on the earth surface as lakes and tanks.

The surface run off and the sub-surface run off finally reaches the ocean and then gets into atmosphere due to evaporation. Thus a chain of events takes place to complete a cyclic movement of water from the atmosphere to the earth and from the earth to the atmosphere. This process of exchange of water is known as **hydrological cycle.**

Global Water Balance

The only input in the world hydrological cycle is precipitation. Every year the whole earth receives mean annual precipitation of 85·7 cms. For the purpose of understanding the principles underlain the global water balance this has been taken as 100 units. Of the 100 units which falls on the earth surface about 16 units has been sent back to the atmosphere by way of evaporation from the land and by way of transpiration from the vegetations. The remaining 7 units run over the surface as rivers and streams and finally reaches the ocean. The ocean which has 77 units of direct precipitation return—84 units of water to the atmosphere including the surface and sub-surface flow (7 units) from the land. Thus a balance between the total incoming water and the outgoing water is achieved (Fig. 26.2).

Evaporation

Evaporation is a process in which the water or ice change its physical state from solid or liquid state to that of a gaseous state. The solar radiation is the main source of energy in converting ice or water into water vapour. About 540 calories of heat is necessary to evaporate 1 gm of water at 100°C and 600 calories at 0°C. The heat energy which is taken in the process of evaporation is liberated in the atmosphere at the time of condensation. And this is recirculated to evaporate the water in the water moisture.

The wind system affects the rate of evaporation. Similarly evaporaiion is also controlled by the temperature of the evaporating surface. The evaporation rate will be higher in the fresh water zone whereas the evaporation will be at a slower phase in the saline ocean water.

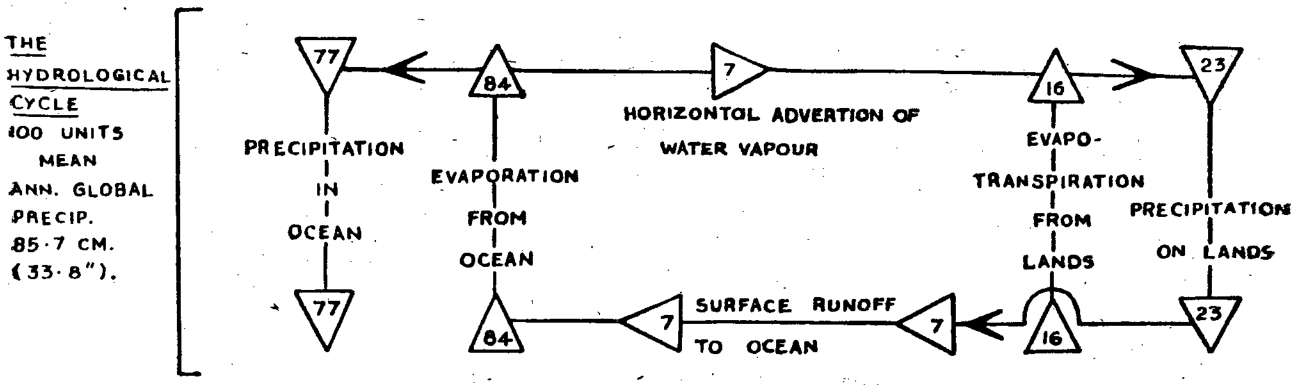

FIG. 26.2 Global Water Balance

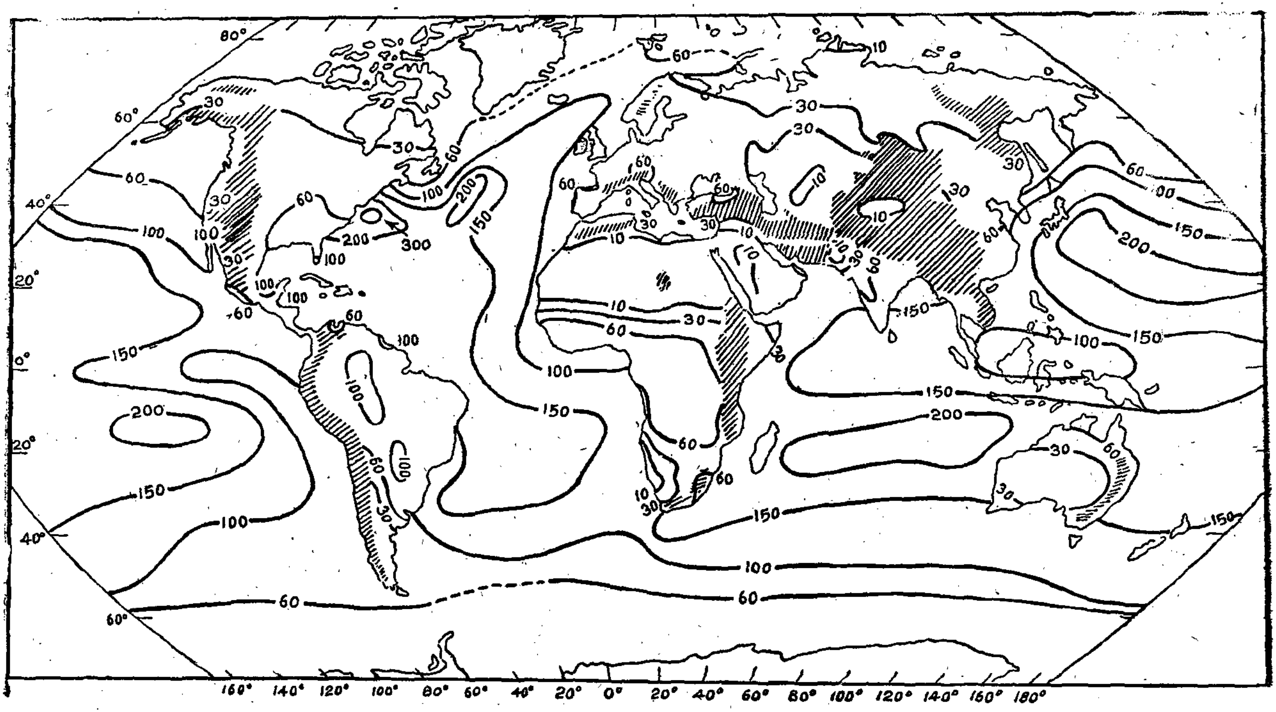

FIG. 26.3 Annual Evaporation

Generally the rate of evaporation is very high at the equator and it decreases towards the poles. The maximum evaporation rate in equatorial region is marked only over the land surface and not on the ocean surfaces due to thick equatorial forests. The evaporation rate is very high on the oceans where the warm and cold currents meet together. Gulf stream in Atlantic and Kuroshio currents in Pacific are the best examples. Here the rate of evaporation is very high, exceeding 200 cms / year especially in winter.

Every year on an average about of 400,000 cu. km of water gets evaporated from the earth, of which ocean surface accounts for 335,000 cu. km of water and the land surface accounts 65,000 cu. km of water. Generally the evaporation rate is reduced by clouds, which prevent incoming solar radiation.

Transpiration

When the vapour pressure in the atmosphere goes down than that of the leaf cells, the water loss takes place from vegetation in the form of evaporation. This is called **transpiration.** Generally an ordinary tree may absorb and transpire 200 litres of water per day. The actual amount of transpiration from a tree exceeds the actual requirements of a tree. Most of the water from the tree is left only during the day time because of the small bores or stomata through which the water escapes into the atmosphere, opens in response to the solar radiation. The combined effect of evaporation and transpiration is known as **evapo-transpiration.**

Precipitation

The evaporated water which gets into the atmosphere in the form of water vapour falls as precipitation, once the stage of condensation is reached. The precipitation can be divided into 3 types, (1) Orographic, (2) Convectional and (3) Frontal (For further details refer the chapter on Precipitation).

Surface Flow

A portion of the precipitation which falls on the surface of the earth runs as streams and rivers. The surface flow is of recent significance to the man because he is able to use them for irrigation, power generation for domestic and industrial uses. The

streams are divided into perennial and non-perennial streams. The water flows throughout the year in the perennial rivers, for example river Ganga. Whereas in the non-perennial rivers the water flows only for a part of a year, for example River Cauvery or River Vaigai. Generally the surface flow depends upon the intensity, direction and frequency of the precipitation, the geology of the region, i.e. the permeable nature of the rocks.

Undergound Water

Some amount of water which falls on the earth surface in the form of rainfall sinks through the joints or the pores of the rocky strata. Such water which get collected underneath the surface of the earth, within the zone of saturation, where the atmosphere pressure is equal or less than that of the hydrostatic pressure is known as **groundwater.**

The water bearing rock formations which yield the large flow of water to make up the natural underground reservoirs are called **acquifers.** They vary in size, shape and spread.

The availability of large quantity of water in an acquifer is determined by two important factors. They are porosity and permeability of the rock. The porosity can be defined as the ratio between the volume of pores or interstices in a material to the bulk (total) volume of the same material. The water storage capacity of a material is determined by the porosity. Permeability of the rock strata depends upon the free movement of water through pore space and joints. If a particular rock does not permit the free movement of water through it then it is called as impermeable rock. A formation which is highly porous need not be as permeable media, clay for example is highly porous and can hold a large quantum of water but the pores are so minute and hence they do not allow the water to get in easily, thus it is relatively an impermeable media. Gravel, sands and any other dense rock that has joints because of the earth movements are some of the permeable rocky strata.

Unconsolidated Materials

In the materials the pores are not cemented together. So these materials are highly permeable (e.g. Sandstone).

Indurated Earth Materials

In the indurated earth materials the pores are cemented together due to the chemical precipitation of salts in the rocks. Hence these do not allow the penetration of water through them. These are known as the impermeable materials. e.g. Shale.

The amount of groundwater storage therefore depends upon the physical properties of the geological formations.

The upper surface of the zone of saturation in unconfined permeable rock is called the **water table.** The water table is a dynamic one in the sense that it varies from place to place, season to season. For example in the humid area or where the rocky surface is permeable and the water table will be very close to the surface for example, Thanjavur Delta. In the relatively dry areas or where the rocky surface is non-permeable than the water table will be very low to the surface for example Coimbatore, Dharmapuri region. In most part of the Tamilnadu one can notice even in their houses, that the water level in the wells go down when the summer is on and the water level rises up as the North-East Monsoon sets in Winter. Since the precipitation re-charges the groundwater storage the level of water rises in the well.

Sometimes a body of water is separated or stored away from the groundwater because of the impermeable rock strata. Such a saturated storage of groundwater is called as **perched groundwater** (Fig. 26.4).

A slow flow of water will emerge from the ground if a perched water table meets a valley side. Such a flow is known as **spring** or **seep.**

Artesian water is that which flows upward towards the ground surface through its high pressure. This is possible when the water bearing rocks are overlaid by an impermeable rock. When this condition prevails the water is under higher pressure and if a well is sunk to it the water will rise automatically. The name Artesian is derived after the French province of Artois, where the first ever flowing wells were sunk in 1126 A.D. (Fig. 26.5).

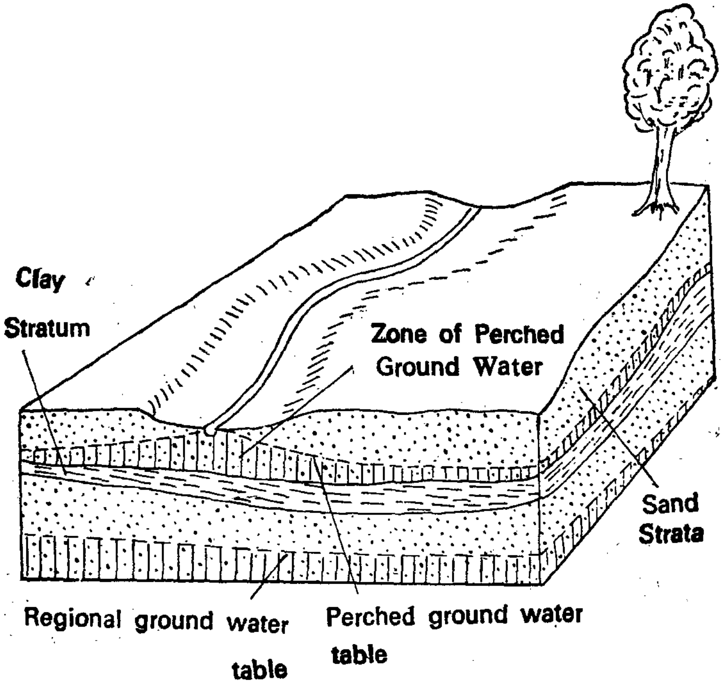

FIG. 26.4 Perched Ground Water

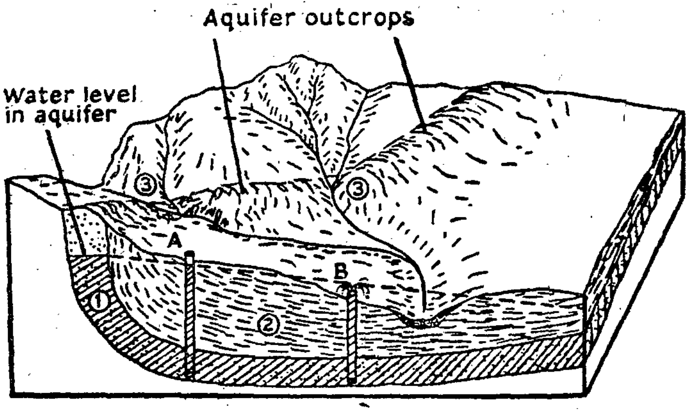

FIG. 26.5 An Artesian Ground Water System

How to enrich the underground water storage?

The underground water storage mainly depends upon the absorptive capacity of the soil and the rock strata, the topography, the type of vegetation cover, precipitation form and the intensity and frequency. These factors will determine the quantity of precipitation that will sink into land surface or flow as surface run off.

In some areas where the surface or sub-surface rocks are impermeable much of the precipitation which occur there will go as surface run off. Thus the soil erosion will be greater in these areas or this can be prevented by having a good vegetational cover. Man can recharge the underground water storage in an area, if the area is highly permeable, by storing flood waters of the rivers by daming it. The rapidly growing settlements greatly reduce the opportunity for groundwater recycle because much of the land is covered by industrial, residential and commercial establishments.

QUESTIONS

I. Short answer questions :

1. Define Hydrology.
2. What is an acquifer ?
3. Define water table.
4. What is a perched water table ?
5. What is an artesian well ?

II. Long answer questions :

1. Explain the salient features of Hydrological cycle.
2. Give an account of underground water.

CHAPTER XXVII

OCEANS

Why Study Oceans?

Water is an absolute necessity to life. Human bodies consist mostly of water. It also makes up a larger proportion of human food. As human society advances in its material civilization the demand for water has become manifold

The ocean basins are the large receptacles of virtually all the waters of the planet earth. It affects profoundly the character and composition of the atmosphere, which in turn modifies the climates of the globe. Until recently oceans were considered as only a secondary source of food and a highway for commercial shipping. But the recent explosive growth of human population has focused the attention of man on the resources of the oceans Today he looks upon it as a new frontier for the exploitation of minerals, chemicals, energy and food. Attempts are made to produce drinking water from seawater by a process called desalination. This apart, the oceans are estimated to contain chemical elements of very high potential value, deposits of gas, oil, sulpher potash and coal, metallic nodules and vast marine fisheries. The exploitation of marine fisheries for human consumption is expected to reduce the ever increasing population pressure.

Hence an understanding of the various aspects and characteristics of the oceans is considered appropriate and relevant as well.

Hydrosphere

The most characteristic feature of the earth is the presence of water on its surface. The earth is therefore appropriately described as the 'Water planet'. This thin envelope of water around the earth together with the waters in the underground is called the **hydrosphere** (Fig. 27.1 & Table I). Oceans alone contain 86% of the total water of the Hydrosphere.

The inter-connected waterbody of the earth's surface is known as the world ocean. The large water bodies lying between the continents are the individual oceans. Portions of the oceans which are partially enclosed are known as seas and gulfs.

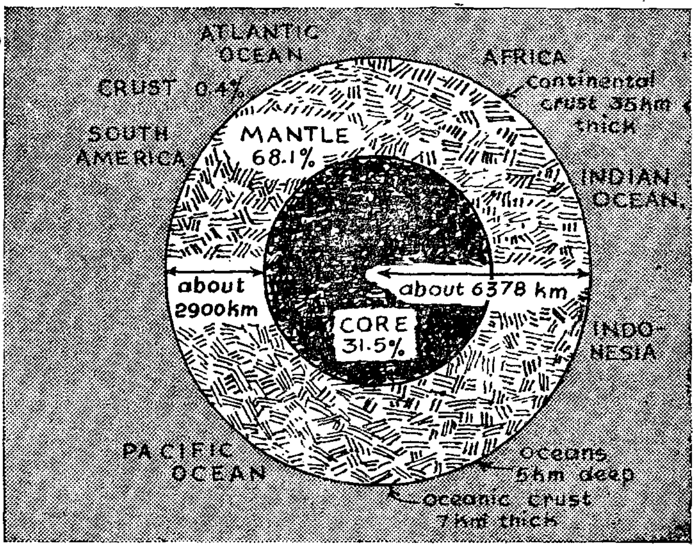

FIG. 27.1 Hydrosphere

The total area of the surface of the earth is 510 mi. sq. km. Of this the world ocean occupies 361 mi. sq. km. (or 70.78%) and land 149 mi. sq. km. (or 29.2%) [Table II]. The distribution of land and water on the surface of the earth is unequal. Their distribution by hemispheres is also unequal. 39.3% of the area of Northern Hemisphere is land and 60.7% water; whereas 19.1% of the Southern Hemisphere is land and 80.9% water (Fig. 27.2 & Table III).

The Continents—North America, South America and Africa—are almost triangular in shape. Their sharpest points are pointing towards the south. On the other hand the oceans extend northwards from Antarctica as three large 'gulfs'. These three large 'gulfs' are the Atlantic Ocean, the Pacific Ocean and the Indian Ocean. The Arctic is generally considered as a land locked arm of the Atlantic ocean (Fig. 27.3).

TABLE I

Distribution of the ocean basins and coastal blocks

	Volume in Percentage
Core	31.5
Mantle	68.1
Crust (including crust).	0.4
Total ...	100.00

TABLE II

Distribution of land and water on the earth's surface

	Millions of	
	Sq. Miles.	Sq. km.
Land	57.5	149
Oceans and Seas ...	139·4	361
Total ...	196·9	510

TABLE III

Distribution of land water by Hemisphere

	Land %	Water %
Northern Hemisphere	39·3	60.7
Southern Hemisphere ...	19·1	80.9

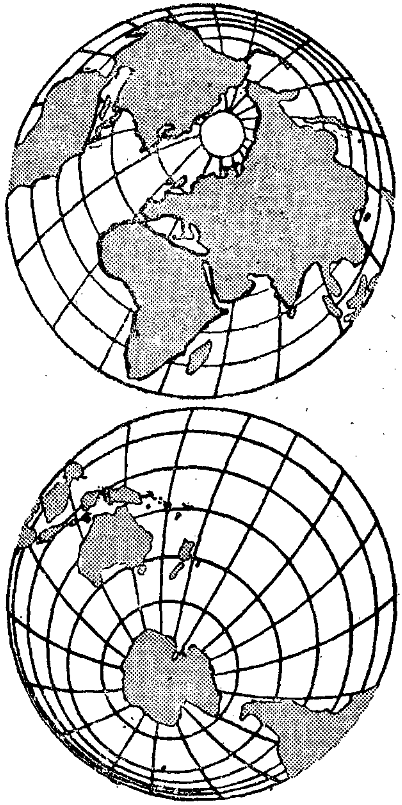

FIG. 27.2 Land and Sea Distribution

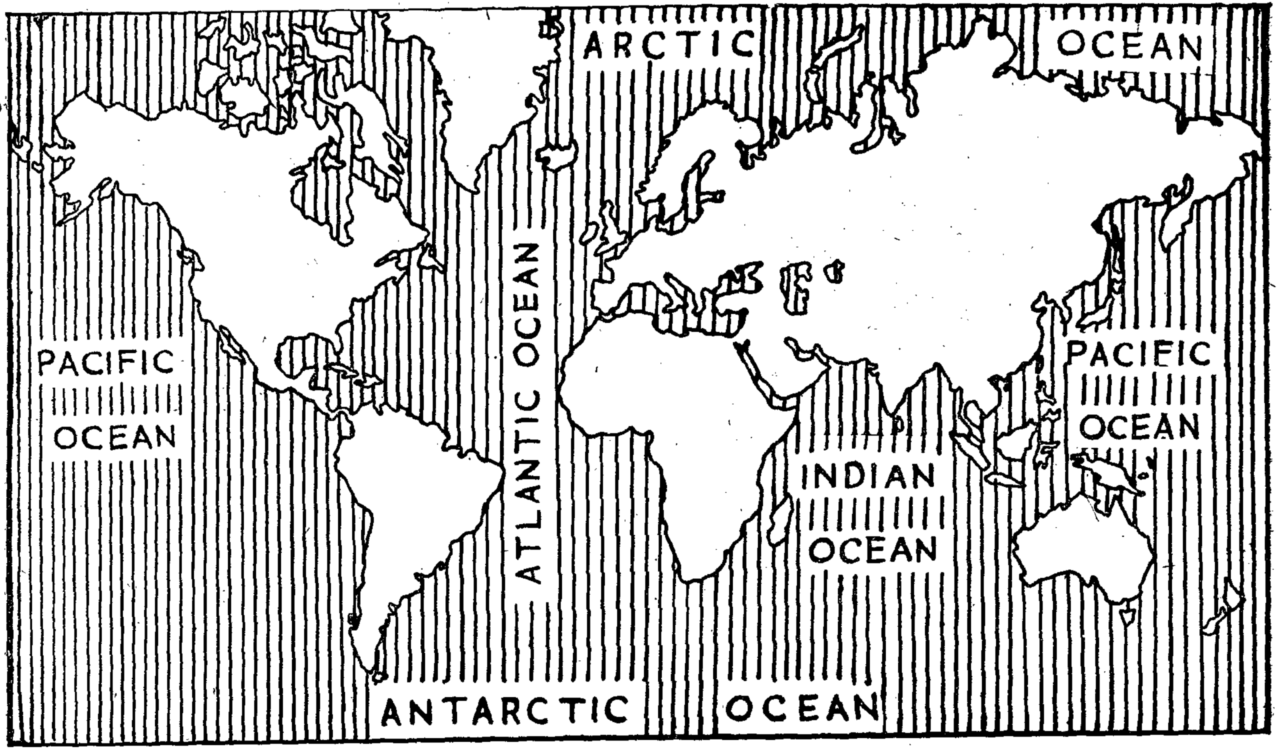

FIG. 27.3 World Map Highlighting the Oceans

Ocean Basins

These three ocean basins have distinct boundaries separating them in the Northern Hemisphere In the Southern Hemisphere 20°E meridian separates the Indian Ocean from the Atlantic; 147°E meridian draws the boundary between the Pacific and the Indian Ocean; and 70°W meridian is the boundary between the Pacific and the Atlantic Oceans.

Pacific Ocean

Pacific is the largest of the three ocean basins (Table IV). It has an area of 180 mi. sq. km and extends for over 17,000 kilometres from the shores of the S America to Indonesia. It stretches, east-west to a distance equal to one half of the circumference of the earth. It also contains more than 50% of earth's water. The Gulf of California, Scotia Sea, South China Sea,

TABLE IV

Area and average depth of the ocean basins

Oceans			Area (in sq. km.)	Depth (in metre)
Pacific	...	...	180	3940
Atlandic	...	...	107	3310
Indian	...	...	74	3840
World Ocean	...	...	361	3730

East China Sea, the Sea of Japan, the Sea of Okhotsk and the Bering Sea are the important marginal seas of the Pacific Ocean. It contains many islands and island arcs—the Aleutians, the Japanese Islands and the Philippine Islands. A land area of 19 mi. sq. km drain into this Ocean. The average depth of the Pacific ocean is 3940 metres. It reaches its maximum depth in the Challenge Deep (11034 m) in the Mariana Trench.

Atlantic Ocean

Atlantic is relatively a narrow ocean basin. It stretches to a maximum width of 5000 km. It has an irregular twisting shape and a remarkably parallel coastline. This S-shaped ocean basin is the only direct connection between the North and South poles. The total waterspread area of the Atlantic is about 17 mi. sq. km. The Amazon, the Congo are the two largest rivers of the world which directly drain into the Atlantic. Besides many other large rivers like the Mississippi and St. Lawrence drain into its marginal seas. The average depth of the Atlantic is 3310 metres. It is the warmest and saltiest of the three oceans (Table V).

TABLE V

Average Temperature and Salinity of the World Oceans

	Temp. (°C)	Salinity (%)
Pacific	3·36	34·62
Indian	3·72	34·76
Atlantic	3·73	34·90
World Ocean ...	3·52	34·72

The extended arm of the Atlantic—the Arctic Ocean—is completely surrounded by the Eurasian landmass and the North American Continent. The unique feature of the Arctic is that it is permanently covered by pack ice to a depth of 3 to 4 metres.

Indian Ocean

The Indian ocean lies more or less in the Southern Hemisphere. This is the smallest of the three oceans and has an area of 74 mi. sq. km. Triangular in shape the base of the Indian Ocean lies in the Antarctica. Three major rivers namely, the

Ganga, the Brahmaputra and the Indus discharge into the Indian Ocean. It has a drainage basin of 13 mi. sq. km. The average depth of the Indian Ocean is 3840 metres.

QUESTIONS

I. Short answer questions :

1. Enumerate the importance of water and mass.
2. What is desalination ?
3. Define hydrosphere.
4. State the proportions of water on the earth.
5. Identify the ocean basins.
6. State the extents of the Pacific, Atlantic and Indian Oceans.

II. Long answer question :

Give a detailed account of the distribution of water on the earth.

CHAPTER XXVIII

RELIEF OF THE OCEAN FLOOR

Mapping the sea floor is a difficult task compared to mapping the land surface. It is so because water does not permit the sea bottom to be directly observed. Hence indirect means of surveying have to be devised for charting the ocean bottom relief. The depth at any point is determined by a method called 'Echo Sounding'. The ocean waters are nearly transparent to sound waves. A strong sound pulse is sent down from a ship. It hits the sea floor and returns back to the ship. The interval between the transmission and return of the echo help determine the depth of that point. Combining thousands of such depth measurements map of the seafloor is prepared. Such maps or charts are called bathymetric charts. Cross-sectional views or profiles prepared from them reveal the many characteristic features of the seafloor. It clearly depicts the steep slopes that separate the deep waters from the shallow waters at the margins of the ocean. Based on this bathymetric charts the oceanfloor is divided into three distinct provinces :

(1) The Continental Margins

(2) Oceanic Rises

(3) Ocean Basins

Continental Margins

The zone where the continents merge into the ocean basins is called the **continental margin.** It consists of the continental shelf, the continental slope and the continental rise.

Continental Shelf

The submerged portions of the edges of the continents is called the continental slope. It is relatively a flat platform, extending

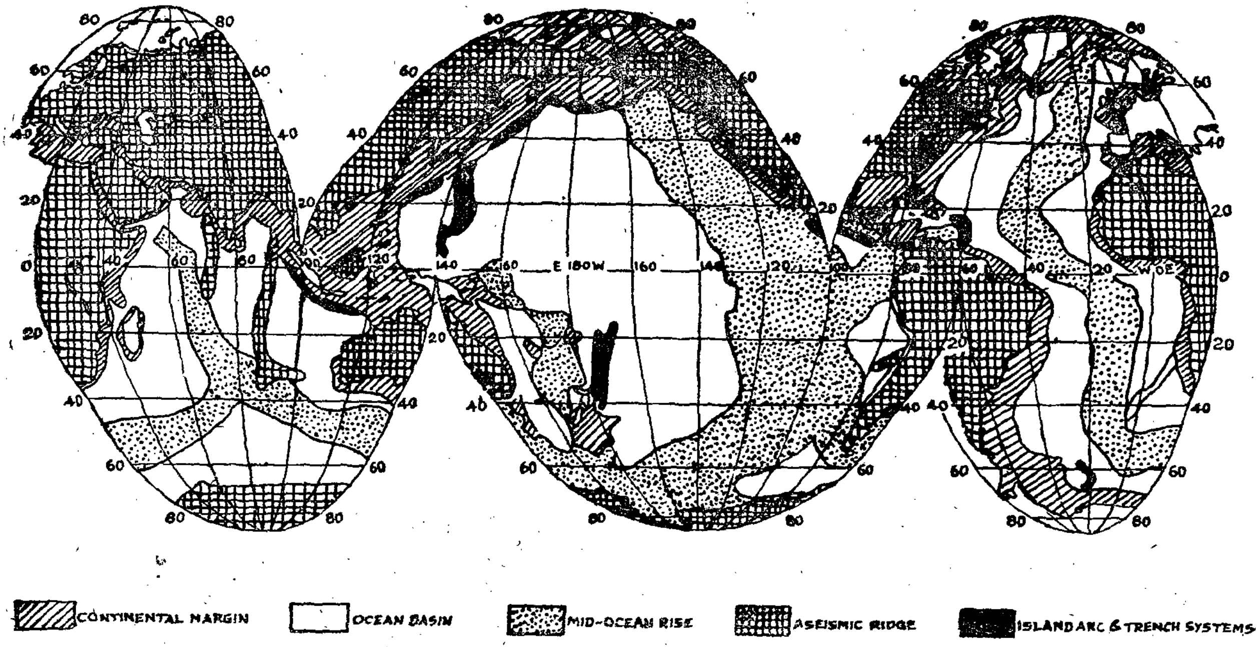

FIG. 28.1 Oceanic Provinces

up to a depth of 130 metres. It uniformly extends up to a distance of 65 km from the shore line and has an average slope of 1°. Its general dimensions like width, depth, and slope, depend on the nature of the nearby coasts. The **continental shelf** is found to be

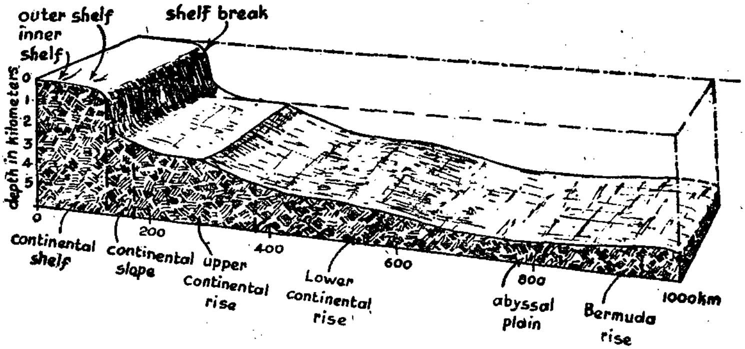

FIG. 28.2 Ocean Profile

quite narrow and deep or even sometimes missing when the adjoining coastal plain is narrow and mountainous. But adjacent to the broad and smooth coastal plains the relief of the continental shelf tends to be much smoother and gently rolling. Hence the coastal plain is appropriately described as the terrestial extension of the continental shelf.

Continental Slope

At the outer edge of the continental shelf the sea floor descends sharply into the ocean basins. The upper portion of this relatively narrow and steeply inclined surface is known as the **continental slope.** It generally ranges in elevation between 1 to 10 km; yet it is not precipitous. It has an average of 4°. Adjacent to young mountain areas and adjacent to rivers which deposit large quantities of sediments the slope steepens to 5°—25°.

Continental Rise

Where the continental slope decreases in gradient to 0.3° or 0.5° the **continental rise** begins. It is the smooth surfaced accumulation of sediments carried from the continents and deposited at the base of the continental slope. It is the long and broad elevation which arises gently from the ocean floor.

Oceanic Rise

Mountain ranges of comparable height and extent exist on the seafloor also. They are described as **oceanic rises** or **oceanic ridges.** They are generally found in mid ocean locations and run

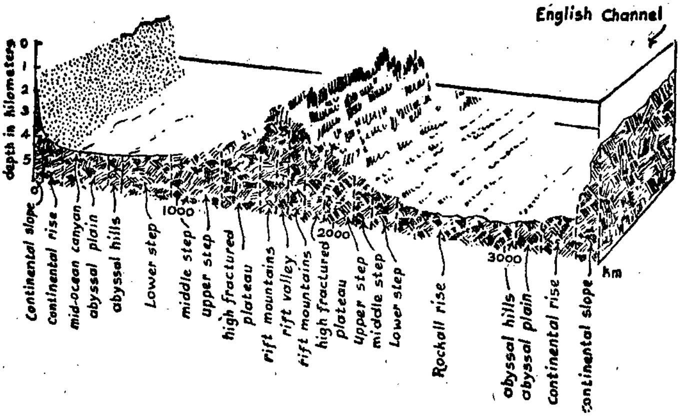

FIG. 28.3 Cross-section of Atlantic Sea Floor

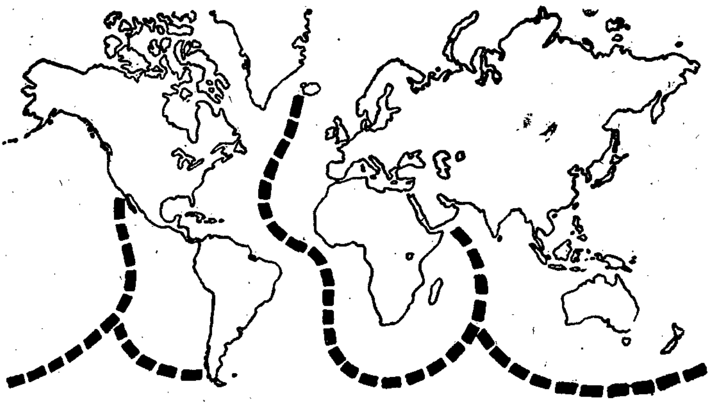

FIG. 28.4 Mid Ocean Ridges (in Dashed Lines)

parallel to the major land masses. The oceanic ridges comprise a single system connected in all the ocean basins. They are generally found to have a steep sided valley called rift valley—in the centre

with rugged mountains on either sides and gentle foot-hills at their margins.

Ocean Basin

The ocean basins are located between the continental margins and oceanic rises. These basins contain a number of distinct topographic features like abyssal plains (deep sea plains), sea-mounts, deep sea hills (abyssal hills) and deeps and trenches. The floors of the oceanic basins are found covered with a fairly thick sediment of 300 metres.

Abyssal Plains or Deep Sea Plains

A greater portion of the seafloor is formed by deep sea plain. It is not a level plain, but due to its vastness and slight slope it appears like a plain. Its surface is covered by sediments of dead organisms and volcanic ashes.

The Deeps and Trenches

The **trenches** are narrow depressions on the seafloor. They are deeper than the deep sea plains with steep sides. They occur on the margins of coasts bordered by continental mountain ranges or island arcs. Their depths normally range from 7 to 10 km. The slope of the steep sides range from 4 to 45°. The deepest part of the world oceans occurs in the Challenger Deep (11034 metres) in the Mariana Trench. This trench runs to a length of 2550 metres and is 70 km wide. The Pacific ocean abounds in trenches (Table I). Very few trenches are found in the Atlantic and Indian Oceans.

Sea-mounts and Islands

The seafloor is a highly irregular surface. Many volcanic extrusions rise abruptly from the seafloor to elevations less than 1000 metres. These are known as **abyssal hills**. Hills rising to elevations of more than 1000 metres are called **sea-mounts**. If these hills and seamounts rise to still greater heights and stand above the sea surface they are called **islands**.

TABLE I

Trenches of the world ocean

Trench		Depth (km)	Length (km)	Width (km)
Pacific Ocean—				
Kurile-Kanchalka	...	10.5	2200	120
Japan Trench	...	8.4	800	100
Bonin Trench	...	9.8	800	90
Mariana Trench	...	11.0	2550	70
Philippines ...	...	10.5	1400	60
Tonga Trench	...	10.8	1400	55
Kermedec ...	...	10.0	1500	40
Aleuntian ...	...	7.7	3700	56
Tm. Am. Trench	...	6.7	2800	40
Peru Chile ...	...	8.1	5900	100
Indian Ocean—				
Java Trench	...	7.5	4500	80
Atlantic Ocean—				
Puerto Rico ...	...	8.4	1550	120
S. Sandwich Tr.	...	8.4	1450	90
Romanchie Tr.	...	7.9	300	60

Relief of the Atlantic Floor*

The Atlantic ocean has a well marked continental shelf. It is fairly broader in the North Atlantic. The deep sea plains of the Atlantic are not of uniform depth. They gradually rise towards the middle from both east and west into the mid-Atlantic Ridge. This is a very well formed oceanic ridge which has a width of 1000 km. It runs the full length of the Atlantic ocean thus dividing it into two longitudinal zones. Its rugged topography rises from the nearby seafloor to a height of 1 to 3 km and break the water surface to form islands like the Azoues, Ascension and Tristan da Cunha. Near the equator this ridge system is cut by the Romanche Trench. The northern Ridge is known as the Dolphin Rise and the southern ridge as the Challenger rise. The Wyvill Thomson Ridge separates the Arctic from the Atlantic seafloor. The Atlantic ocean has very few deeps. Romanche Trench, and Blake Deep are the two important deeps. Atlantic ocean reaches its maximum depth in the Blake Deep (5511 metres) near Puerto Rico Islands.

Pacific Ocean Floor

The relief of the Pacific floor is somewhat complex than the Atlantic. The continental shelf in the Pacific is either extremely narrow or completely absent. The continental edge desends abruptly into the deep sea basin. It is often disrupted by isolated plateaux. These plateaux sometime break the water surface and appear as island arcs. Such islands and island arcs abound in the western and southern Pacific ocean. The ridge system in the Pacific ocean is not well formed as in the Atlantic. It resembles an extensive plateau and extends from Central America to Antarctica through the south of New Zealand. The Pacific has a number of deeps and trenches. These trenches normally occur near the margins of the island arcs and submarine plateaux. The deepest trench of the Pacific Ocean and in fact the world ocean is the Mariana Trench. The Challenger Deep in the Mariana Trench has a depth of 11034 metres.

Indian Ocean Floor

The Indian Ocean floor, like the Atlantic, has a fairly wider continental shelf. The ocean basin is characterised by a mid-

* Fig. 28.5—See at the end of the book.

ocean ridge called the Mid Indian Ridge. It rises from an expansive submarine plateau near the Antarctica. This runs towards the Socotra Island at the entrance of the Red Sea. Here it is known as Carlsberg Ridge. Another branch runs up to the Indian sub-continent to the north of Karachi. This ridge is called the Murray Ridge. The Indian ocean is deeper near Australia and has a few deeps. The Java trench has a depth of 7500 metres. The average depth of the Indian Ocean is 3840 metres.

QUESTIONS

I. Short answer questions :

1. Why is mapping of the sea difficult ?
2. What is Echo Sounding ?
3. State the major oceanic provinces.
4. Define the continental margins.
5. What is continental Shelf ?
6. What is the average slope of the Continental Slope ?
7. Defie the Oceanic Rises or Ridges ?
8. What is a Seamount ?
9. State the greatest depth of the world oceans.

II. Long answer questions :

1. State the broad division of the ocean basin into provinces and discuss their characteristic features.
2. Attempt a comprehensive account of the relief of the Atlantic Ocean floor.

CHAPTER XXIX

OCEAN TEMPERATURE

Sea Water

The ocean basins contain water collected over millions of years. When the importance of oceans is stressed, as determining the nature of this planet, the focus is not on the depressions which hold water but on the sea water itself. It profoundly influences the temperature and precipitation of the adjoining land masses. It also controls climatic variations and through them the distribution of soils and vegetation. A brief appraisal of its properties like temperature and salinity and chemical composition helps in understanding the ocean waters.

Temperature

Temperature is an important property of sea water responsible for the constant restlessness of the oceans. Along with salinity and density, temperature causes various movements of ocean waters like waves, tides and currents.

Sources

The sun is virtually the only source of heat to the seawater. But only a part of the radiation emanating from the sun is used in heating up the ocean. Energy thus radiated by the sun passes into the seawater and is converted into heat energy raising the temperature of water. The amount of heat received from solar insolation is more in the low latitude than in the high latitude. So the ocean surface is unequally heated throughout the world ocean. Because of the curvature of the earth input of insolation is greatest directly beneath the sun (low latitudes) and decreases towards the poles. In addition length of the day, amount of clouds in the sky and salinity are the other factors which affect the receipt of solar insolation. The other sources of energy are :

(1) Radiation from the sky.

(2) Transfer of heat by convectional currents through the deeps and trenches of the ocean floor from the interior of the earth.

(3) Kinetic energy is transformed into heat energy by sea-water.

(4) Heat is also released as a result of chemical processes in the sea water.

(5) Heat energy is also released as a result of water vapour condensation.

Distribution of Temperature

The general distribution of temperature of the world ocean differs both horizontally and also vertically. The controlling factors are many and complex. Latitude, addition of fresh water, excess of evaporation, upwelling or sinking of sea water, salinity, winds, storms and cyclones and relief of the seafloor are the factors responsible for the variable nature of temperature distribution.

Horizontal Distribution

Latitude is the major factor which controls the horizontal distribution. Maximum temperatures are found to prevail in the equational regions of the world. [Table I (a)]. Northwards from the equator temperature decreases till the poles [Table I (b)]. The rate of decrease is 0·3° centigrade per latitude. But the highest temperatures occur a little to the north of the equator—around 5° north parallel. This line which moves with the southward migration of the sun does not cross the equator. This line is known as **thermal equator**. The average temperature in the Northern Hemisphere exceeds that of the Southern Hemisphere. The reason is that land constitutes a major proportion of Northern hemisphere as against water in Southern Hemisphere. As the ocean water gets thoroughly mixed the temperature of surface water also evens out. The average temperature of world ocean is 3·52°C. The Atlantic is the warmest of the oceans with 3·73°C. The Indian and Pacific oceans have average temperatures of 3·72° and 3·36°C respectively.

Range of temperature

The range of temperature—the difference between the average maximum and average minimum—is considerably lower than that of the land. The annual variation in temperature is largely controlled by varying amounts of solar insolation, ocean currents and

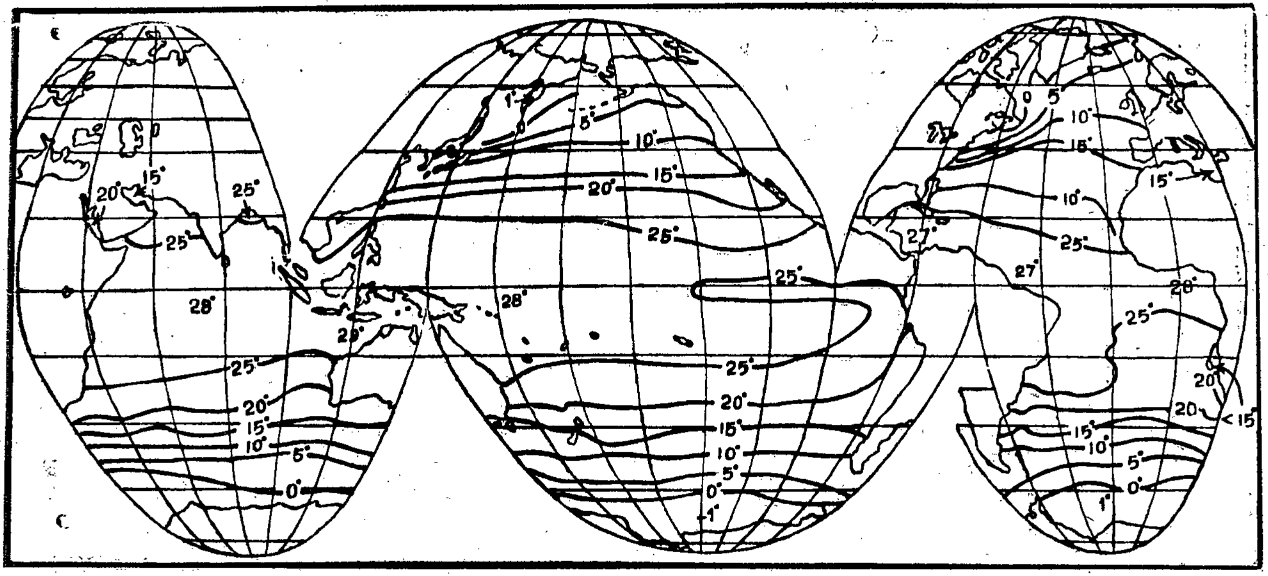

FIG. 29.1 Distribution of Temperature of Oceans—World

TABLE I (*a*)

Latitudinal Distribution of Temperature of Oceans —Northern Hemisphere

(In Degrees Fahrenheit)

Latitude	Pacific	Atlantic	Indian
0 — 10°N	27.20	26.66	27.88
10 — 20	26.42	25.81	27.23
20 — 30	23.38	24.16	26.14
30 — 40	18.62	20.40	—
40 — 50	9.99	13.16	...
50 — 60	5.74	8.66	...
60 — 70	...	5.60	—

TABLE I (*b*)

Latitudinal Distribution of Temperature of Oceans —Southern Hemisphere

(In Degrees Fahrenheit)

Latitude	Pacific	Atlantic	Indian
0 — 10°S	26.01	25.18	27.41
10 — 20	25.11	23.16	25.85
20 — 30	21.53	21.20	22.53
30 — 40	16.98	16.90	17.00
40 — 50	11.16	8.68	8.67
50 — 60	5.00	1.76	1.63
60 — 70	—1.30	—1.30	—1.50

winds. The annual range of temperature is greater in the North Atlantic and North Pacific than in the Southern Hemisphere. This is because of the cold winds blowing from the interior of the continents lowering winter temperatures.

Vertical Distribution

The temperature of sea water decreases with increasing depth. This variation is due to the following factors :

(1) the amount of heat absorbed

(2) conduction effects

(3) changes due to currents and horizontal movements of water masses

(4) vertical motions of sea water and its effects

The upper few hundred feet of sea water has more or less the same temperature as the surface water. This upper layer is a well mixed warmest, layer which only varies seasonally. Below this

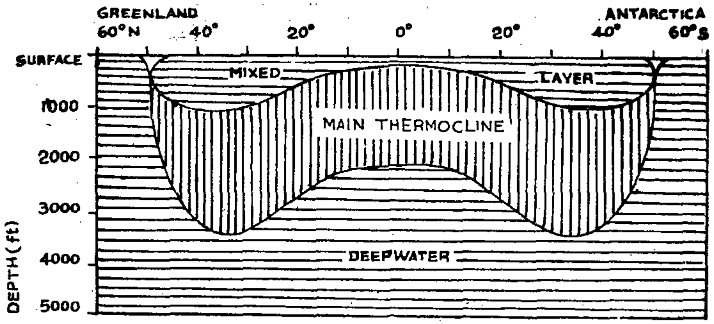

FIG. 29.2 Thermal Layers of Ocean Waters

the rate of decrease is rapid; and still deeper the bulk of the sea water is cold in all latitudes. On this basis three distinct vertical layers of temperature variation are recognised. They are :

(1) the well mixed upper layer whose rate of decrease downwards is very little.

(2) a thin zone of water which is 2500' in thickness whose rate of decrease is rapid. This layer is called the Thermoclyne. The thickness of this layer is much less near the equator and greater near the poles, and

(3) the deep water layer. This accounts for the bulk of the ocean water and extends from the thermoclyne to the seafloor.

QUESTIONS

I. Short answer questions :

1. How does water affect the planet earth ?
2. Identify the sources of heat to sea water.
3. State the factors which control the distribution of temperature of the oceans.

II. Long answer question :

Give an account of the distribution of temperature of the oceans.

CHAPTER XXX

OCEAN SALINITY AND DENSITY

Composition of Sea Water

The complex substance called seawater is 96.5% water and 3.5% salts. It contains millions of living things in fractional proportions and an equal amount of dust. Analysis of sea water has revealed that it has all the chemical elements which occur on the earth. But at least six major elements are in considerable proportion, while the remaining elements are found in traces only (Table I). These six elements alone constitute 99% of the seasalts.

TABLE I

Composition of Sea Water

Salts	Percentage
Chloride (Cl)	55.00
Sulphate (So_4)	7.60
Sodium (Na) — —	30.60
Magnesium (Mg) — —	3.60
Calcium (Ce)	1.10
Potassium (K) — —	1.10
	99.00

Among them sodium (Na) and calcium (Cl) constitute 86% out of the 99% of six salts. The total amount of dissolved salt is measured and expressed as **salinity** of seawater. Salinity is defined as the total amount of solid materials, in grams, contained in

1 kg. of seawater. This is expressed in parts per one thousand parts (‰). One kilogram of seawater on an average contains 35 grams of salts in it (35‰).

Factors Affecting Distribution of Salinity

Salinity of the seawater is not the same everywhere in the world ocean. It is highly variable between places and seasons. It is most easily affected by the following factors :

(1) *Evaporation* increases salinity as the proportion of water is considerably reduced. Regions characterised by excess of evaporation, like the tropical areas, have high salinity.

(2) *Addition of fresh water*, on the other hand, reduces the proportion of dissolved salts, thus reducing salinity.

Precipitation reduces salinity in the low latitudes, *melting ice* in the high latitudes, and *rivers* around the coastal areas.

(3) Salinity is when already dissolved elements or compounds precipitate and are removed from sea water.

(4) Salinity of sea water is also altered when different bodies of water masses possessing different amount of salinity get mixed.

Horizontal Distribution

Salinity is highest in the tropical oceans. This is because of the clear skies and brilliant sunshine which cause rapid evaporation. A maximum salinity of 37‰ is found to prevail in these belts. From the tropics salinity decreases towards the poles as well as towards the equator. Copious rainfall, cloudy skies, calm air and low evaporation contribute to a low salinity of 34‰ and less. Around the poles large quantity of melt water is added and dilutes the surface water. This reduces salinity. Apart from this general pattern, salinity in the Southern Hemisphere is lower than the world average. This is because of thorough mixing of the ocean waters in this hemisphere. The Pacific has an average salinity of 36.42‰. Between the latitudes 20° and 40°N in Pacific, high salinity of 35.5‰ is found to prevail. Salinity is lowest in the yellow sea, namely 30‰ and less.

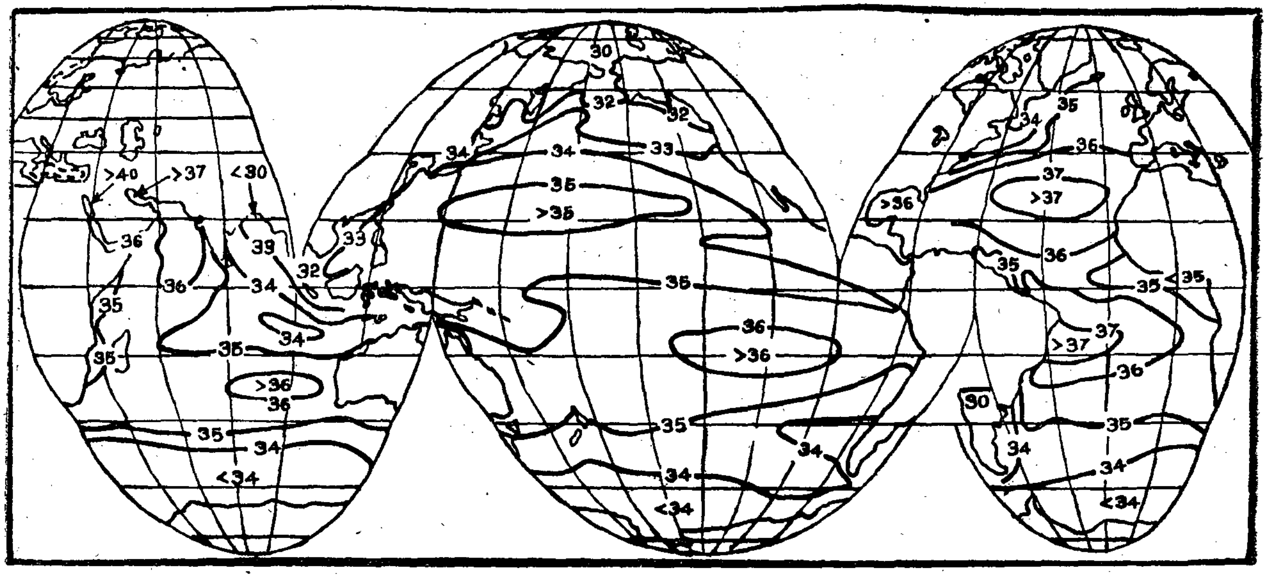

FIG. 30.1 Distribution of Salinity—World

TABLE II

Horizontal Distribution of Salinity for World Oceans

Latitude	Pacific	Atlantic	Indian	World Oceans
40°N	33·64	35·80	...	34·54
35	34·10	36·46	...	35·05
30	34·77	36·79	...	35·56
25	35·00	36·87	...	35·79
20	34·88	36·47	35·05	35·44
15	34·67	35·92	35·07	35·09
10	34·29	35·62	34·92	34·72
5	34·29	34·98	34·82	34·54
0	34·85	35·67	35·14	35·08
5	35·11	35·77	34·93	35·20
10	35·38	36·45	34·57	35·34
15	35·57	36·79	34·75	35·54
20	35·70	36·54	35·15	35·69
25	35·62	36·20	35·45	35·69
30	35·40	35·72	35·89	35·62
35	35·00	35·35	35·60	35·32
40	34·61	34·65	35·10	34·79
45	34·32	34·19	34·25	34·14
50°S	34·16	33·94	33·87	33·99

The Atlantic exhibits greater variations in salinity distributions from the average for this ocean—34.90%. Regions between 20° and 40° in the north Atlantic have high salinity of 37% and more. While the equational belts and the Caribbean have lower salinity 35%. Waters near the mouths of rivers have very low salinities. It is 15% at the mouth of river Amazon, and 20% at the mouth of river Niger (Table II).

The Indian ocean has an average salinity of 34.76%. It ranges between 34% to 36% in the south Indian ocean. In the Bay of Bengal, salinity decreases northwards to the mouth of river Ganga to 36%. In the Arabian Sea salinity increases northwards to 41% in the sea. Partially enclosed seas and lakes exhibit striking differences in salinity. It ranges between 36.5 and 39% in the Mediterranean. This is because Mediterranean receives little rainfall but is subjected to high evaporation. Because of similar conditions the Red Sea has a high salinity of 41% On the otherhand the Black Sea has a low salinity of 18% because of low evaporation and addition of large amount of fresh water by rivers like the Don, the Danube, etc. The Gulf of Karabogaz in the Caspian Sea has a high salinity of 170% as it is subjected to high evaporation. The Dead Sea is the saltiest of the inland lakes with 237·5%. Inland seas have high salinities because of the absence of outlet for the waters which flow in.

Density

Density of sea water is slightly higher than fresh water. Two factors control the density of sea water. They are temperature and salinity. Apart from this addition of fresh water by precipitation and melting ice, and evaporation causes changes in density. Increase in temperature and addition of freshwater lower density, it is increased with increasing temperature and increasing evaporation.

When the density of surface water exceeds that of the layer immediately below, water sinks downwards. This causes a vertical movement in water. While sinking the dense water spreads sideways at intermediate depths. To replace water which sinks downwards water from the sides move in. Thus ocean currents come into existence.

Tropical regions are characterised by high temperature and also salinity. Yet the density of tropical waters remain comparably low. In the high latitudes low temperatures increase the density of water causing it to sink, yet the addition of fresh water in large quantities reduces density relatively. This makes the high latitude waters to sink at the intermediate level itself. Besides ocean is warmer or cooled at its upper surface only. Based on the above facts the ocean is divided into three depth zones. They are : (1) The Surface layer, (2) The Pycnocline and (3) The Deep Zone. The surface layer has an average

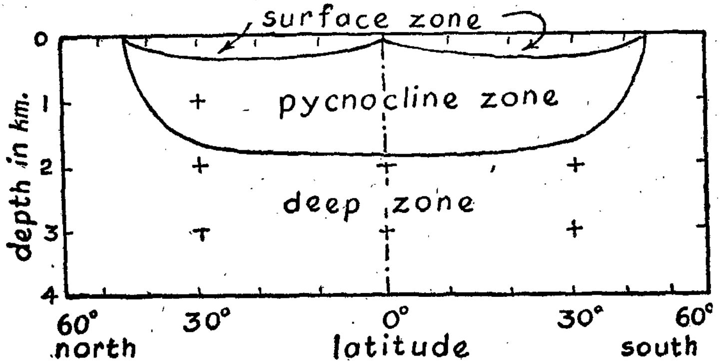

FIG. 30.2 Density Layers of Oceans

depth of 100 metres and comprises 2% of the ocean waters. As this layer is directly in contact with the atmosphere, waters are quite warm except in high latitudes. This is the least dense zone and also abundant in marine food because of the availability of sufficient light for the process of photo-synthesis.

The pycnocline is developed because of marked changes in salinity and temperature. Density, in this layer, changes quite rapidly downwards. In the low latitude pycnocline coincides with the thermoclyne. Pycnocline is a very stable zone which prevents any movement of surface water to the bottom. Yet it permits slow penetration of deep-ocean waters upwards. This zone stretches on an average to a depth of 100 to 2000 metres. The deep zone containing 80% of the ocean waters lies at a depth of 2000 metres and below except at high latitudes. Here the deep water is in contact because of their low temperature.

QUESTIONS

I. Short answer questions :

1. State the elements which comprise the ocean water.
2. State the factors which affect the distribution of salinity.
3. Define salinity.
4. What is the average salinity of oceans?
5. Why salinity is comparatively greater in the island lakes and seas?

II. Long answer question :

Give a detailed account of salinity distribution of the oceans of the world.

CHAPTER XXXI

OCEAN CURRENTS

Movements in the Oceans

Oceans are aptly described as restless waters. They are constantly under motion—motions upward, downward, or sideways, periodic or sporadic. Solar energy, both directly and indirectly and the physical and chemical properties cause various movements of sea water. They are classed under three groups. They are : (1) Currents (2) Tides (3) Waves.

Currents

Currents are large-scale movements—vertically, horizontally and at all depths—of large bodies of sea water. It flows with a specific velocity and also has a direction, path, extent and boundaries. The interaction between the atmosphere and the surface of water causes currents. In the first instance wind exerts pressure on the sea surface and thus causes surface movement of water. Secondly, freezing and evaporation at the sea surface causes differences in density resulting in vertical currents in sea water.

Surface Currents—Causes

Two types of forces cause the surface water to flow. They are : (1) Primary Forces (2) Secondary Forces.

Primary Forces

Wind, gravity, pressure changes and tidal forces are the primary forces responsible for the origin of ocean currents.

Secondary Forces

Frictional forces caused between the ocean bottom and water body and also between water bodies, the coriolis force arising from the rotation of the earth are the secondary forces. These forces do not cause currents by themselves but modify and alter the

courses of currents. Apart from these factors, shape of the continental masses, relief of the sea floor are some of the other factors capable of modifying the currents.

Surface Circulation

The most characteristic feature of general surface circulation is the large circular eddies or gyres (currents moving in a circle) on either side of the equator in the Indian, Pacific and Atlantic oceans. They are found within the tropical and sub-tropical regions.

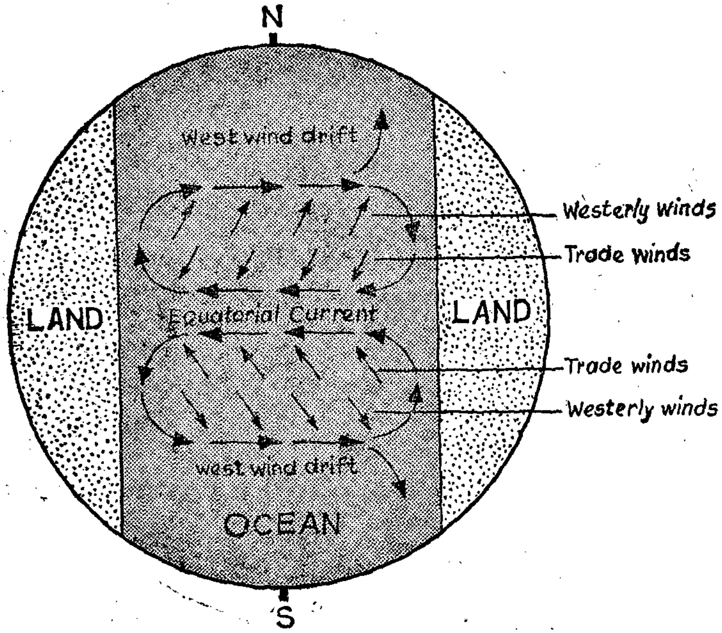

FIG. 31.1 Schematic Diagram Showing Surface Circulation

They are clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere. These major flows are separated by a narrow flow of currents called Equatorial counter currents. They flow eastward and counter to the direction of northern and southern Equatorial currents.

Another, conspicuous feature of these gyres is the east-west flowing current in the westerly belts called West Wind drifts. In the Southern Hemisphere it flows round the Antarctica. This constitutes the largest surface flow and flows freely without any obstructions. In the northern Hemisphere, it is called the North Pacific current in the Pacific, and North Atlantic Drift in the North Atlantic. They are strongly influenced by the continental boundaries.*

The Atlantic Ocean

The equatorial current—the North Equatorial current and South Equatorial current—flow from east to west under the influence of the trade winds. The North Equatorial current as it reaches the western margins of the Atlantic, turns north. A branch passes into the Caribbean and the other branch flows to the west of the West Indian Islands. At the mouth of the Straits of Florida these two branches meet and flow further northward and is called the Florida Current. Beyond Cape Hatteras it is called the Gulf Stream, a well defined, narrow current of very high velocity. The Gulf Stream, as it crosses the North Atlantic is called North Atlantic Current, which branches into two, the North Atlantic Drift and Irmenger Current. North Atlantic Drift turns south washing the coasts of Spain and the Islands of Azones to complete the clockwise circulation.

In the south Atlantic, the South Equatorial current bifurcates in the western Atlantic, one flowing south and the other joining the North Equatorial Current. As it flows south along the coasts of Brazil, it is called the Brazil Current. Around 40°S latitude this current comes under the westerly winds. It flows due east across the Atlantic and is called the South Atlantic Current. In the eastern Atlantic ocean, it turns north along the Benguela coast of Africa. Here it is known as Benguela Current. Flowing further north it joins the South Equatorial Current.

The Equatorial counter current in the Atlantic Ocean is not well developed. It is found only in the Eastern Atlantic. Besides these currents the South Atlantic Ocean is dominated by the West Wind Drift.

* Fig. 31.2—See at the end of the book.

Pacific Ocean

The North Equatorial and South Equatorial currents are well developed in the Pacific Ocean. These broad, deep currents flow westward and on reaching the eastern margins turn northward and southward respectively. The North Equatorial current flowing north in the Eastern Pacific is known as Kuroshio Current. This current is comparable to the Gulf stream of the Atlantic in dimensions and characteristics. It turns due east at 40° north latitude and crosses the North Atlantic with the name North Pacific Current. This current on reaching the eastern margins of the Pacific sends a branch into the Gulf of Alaska. Another branch turns south. This is called California Current. This ultimately joins the North Equatorial Current to complete a clockwise circulation.

In the south Pacific Ocean, the South Equatorial Current, turns south on reaching the western margins and becomes East Australian Current. Turning east at 40° south latitude it flows across the South Pacific to reach the South American coasts when it flows north along the coasts of South America it is called Peru Current. Ultimately this current joins the South Equatorial current to complete a counter clockwise circulation. Like the Atlantic, South Pacific Ocean around the Antarctica is dominated by the West wind drift. The Equatorial counter Current in the Pacific ocean is well developed than in the other two oceans. It flows through the full stretch of the Pacific ocean between the North Equatorial and South Equatorial Currents between 4° and 10°N latitude.

Indian Ocean

The Pattern of currents in the Indian Ocean* differs markedly from the other two oceans. These striking changes are closely associated with the monsoon winds. During the summer months, May to September warm air is drawn towards the Indian sub-continent. During winter, November to March, cold air from the interior of the continents blows over the ocean. The result is in summer the current system moves north with the strong monsoon winds. The North Equatorial Current disappears almost and is replaced by the South-West Monsoon Drift. This

Fig. 31·3—See at the end of the book.

flows from the *north-west to south-east in the Arabian Sea.* In winter, as the winds blow from the north-east the *current systems* move southward. The North Equatorial current reappears and flows from the Andamans to the Somalia Coast. The Equatorial Counter Current which is completely wiped out by the south-west mónsoon winds, reappears between the North and South Equatorial *currents. This flows between the two Equatorial* currents towards east. In the *South Indian Ocean, the South Equatorial* current flows between the coasts of Australia and South Africa. It is deflected southward and is called Agulhas Current. It finally joins the west wind Drift and flows due east till about the South-west coast of Australia. From there it flows northward and is known as West *Australia.* From there it flows northward and is known as West *Australian Current and joins the south* Equatorial Current.

QUESTIONS

I. Short answer questions:

1. What are the various movements of sea water?
2. Define currents.
3. State the factors which cause currents.
4. *Identify the characteristic feature of general circulation* of oceans.
5. What are the counter currents?

II. Long answer questions:

1. Describe the pattern of circulation of the Atlantic Ocean.
2. Give a comprehensive account of the Indian Ocean currents in water and why do they differ from Summer Pattern.

CHAPTER XXXII

OCEAN WAVES

Waves are the disturbances of the ocean surface passing across the water. They are in fact a form of energy, mechanical-energy. This energy is provided to the water by winds, earthquakes, volcanoes, landslides, etc.

Because of their complex nature, waves do not lend themselves for easy definition. Nevertheless, they may be described by their characteristics.

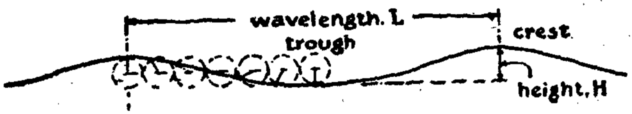

FIG. 32.1 Structure of a Wave

Waves as they move across the water surface produce a complex pattern of tiny hills and valleys. Let us look at a section of the wave which looks like two hills enclosing a valley.

The highest point of the wave is called the crest and the lowest point the trough. The vertical distance between the crest and the succeeding trough is the wave height (H). The horizontal distance between the successive crests or troughs is called the wave length (L). The time taken for the successive crests or successive troughs to pass through a particular point is the wave period (T). This is measured in seconds. The speed of the wave is referred to as celerity Wave length (L). When divided by wave period (T) it gives celerity or wave speed. As the crests and troughs move together it is described as a wave train.

Motions in the Wave

When the waves move, individual particles of water move in circular orbit. This circular orbit is vertical and almost stationary.

The water moves forward as the crest passes, then vertically and finally backward as the trough passes. This orbit is repeated or retraced as each subsequent wave passes. After each wave has passed the water particle is found nearly in its original position,

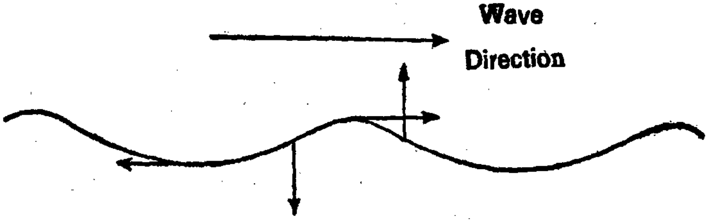

FIG. 32.2 Movement on a Wave

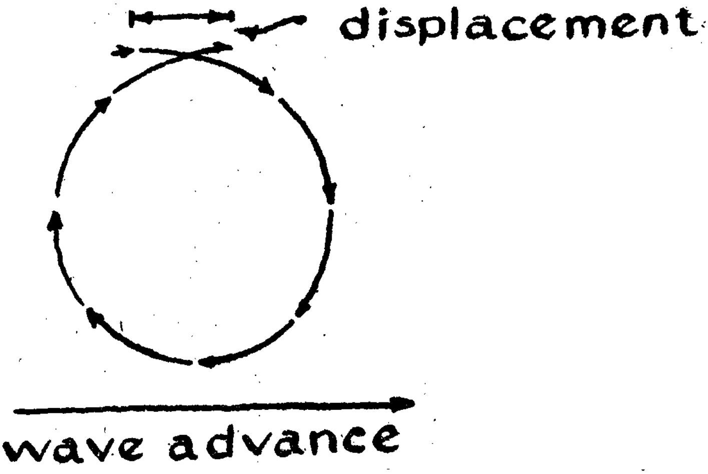

FIG. 32.3 Movement of Water Particle in a Wave

with only a slight net movement. This happens because water moves forward slightly faster as the crest passes than it moves backward under the trough. This slight forward displacement of water is in the direction of the wave motion.

In deep waters where the depth exceeds one half the wavelength (L/2) water parcels move nearly in circular orbit. Such waves

unaffected by the sea floor are known as deep water waves. The diameter of these orbits at the surface will be equal to the wave height. It decreases to one half the wave height at a depth of h/2.

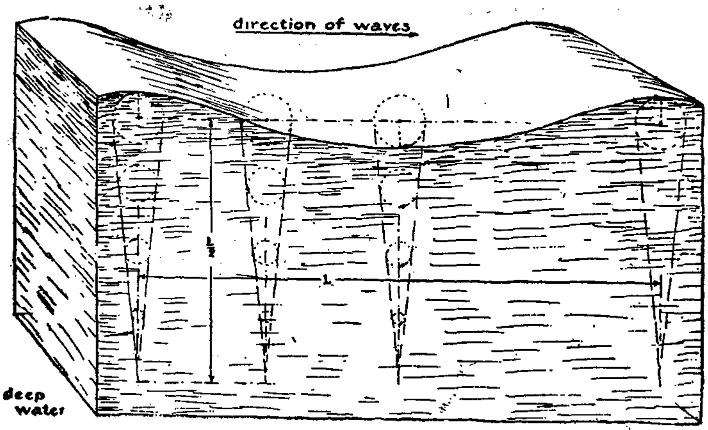

FIG. 32.4 (*a*) Motions in Sea Water

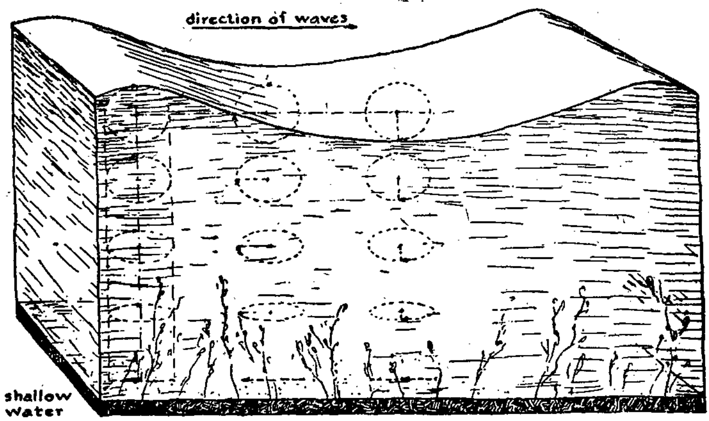

FIG. 32.4 (*b*) Motions in Sea Water

In shallow waters where the depth is less than L/2 the bottom affects the circular orbits of the waves. It gets slightly deformed

and becomes elliptical. Here the floor will be subjected to wave action.

Factors Causing Waves

Waves are primarily caused by winds. Besides the other forces like earthquakes, landslides, the attracting forces of the moon and the sun, and density differences also create waves.

Wind Waves

Most of the waves owe their origin to winds. The waves caused by winds are of many sizes and shapes. They also vary in height and length from a few centimetres to hundreds of metres.

As the wind blows over the smooth surface of the ocean certain amount of energy from the wind is transferred to the sea surface. It takes place by both friction between the wind and water surface and also by pressure fluctuations of the wind. This transfer of mechanical energy manifests in the form of waves. Increasing wind speed imparts greater amount of energy to the waves. It results in the birth of larger waves. Besides, duration of the wind and the distance over which it blows also determine the size of the wave. The property of wind to blow constantly in a direction and also its duration is described as its 'fetch.'

A light air of wind speed between 1 to 5 km causes ripples on the surface of the water. These ripples are called 'Capillary waves.' As the wind continues to blow, the ripples grow gradually into short and choppy waves. Regions of ocean surface where such conditions prevail are called 'the sea.' 'The Sea is the source regions of the waves from where they spread to other parts of the ocean.

Waves Caused by Other Forces

Sudden impulses such as volcanic eruptions or earthquakes may also cause some of the longest waves in the ocean. They move from their place of origin and spread on all sides. Such waves caused by volcanoes or earthquakes are very highly destructive. They are also capable of travelling over longer distances. They are called 'Tsunanus' or 'seismic sea waves.' Waves

caused by landslide are known to affect only a small area. All these waves are called 'free waves.' Because the force responsible is not continuously applied. Once the force ceases further waves are not caused.

The attraction of the sun and the moon causes the longest waves of all. They are called the 'Tides,' which are continuously moving waves. They are also called 'forced waves' because the attractive forces of the sun and the moon are applied continuously.

QUESTIONS

I. Short answer questions :

1. Describe a wave.
2. What is wavelength ?
3. Why the sea floor in shallow waters is subjected to wave action ?
4. State the factors causing the waves.
5. What is Tsunanus ?

II. Long answer question :

Describe in detail the characteristic properties of a wave.

CHAPTER XXXIII

OCEAN TIDES

Tides are the alternate rising and falling of sea level at a given point. The gravitational forces exerted by the moon and the sun on the earth is the cause of such daily cyclical changes. A rise in sea level in a day is called the high tide and a fall, the low tide.

Tide Creating Forces

The earth, the sun and the moon are drawn towards each other by the forces of their gravitational attraction. But they are kept apart from colliding against each other by their centrifugal forces.

The moon exerts greater influence on the earth in creating the tides. The centrifugal force of the earth is equal to the attraction of the moon at the centre of the earth. The strength of gravitational pull as exerted on any other planet varies with distance. The gravitational force increases with decreasing distance, and it decreases with increasing distance whereas the centrifugal force remains the same at the centre of the planet and is toward the same direction.

The side of the earth facing the moon is near to it by a distance equal to the radius of the earth. Hence the gravitational

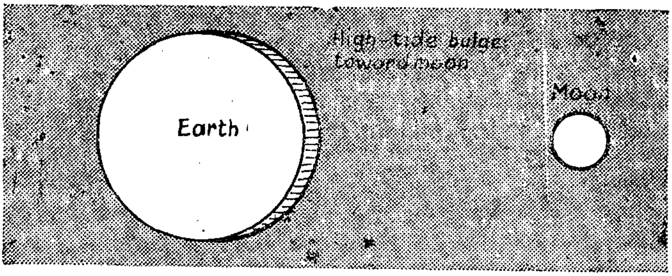

FIG. 33.1 Formation of Tidal Bulge by the Gravitational Attraction of the Moon

pull of the moon on this side will be greater than at the centre. It will be more by 3.3%. As each particle on the earth responds equally to the pull of the moon, the waters of the ocean are also attracted toward the side facing the moon. This causes a bulge of water on this side.

At the sametime the side of the earth facing away from the moon will be farther from it by a distance equal to the radius of the earth from its centre. Hence the gravitational attraction of the moon will be less than the amount on the side facing it. Here the centrifugal force will be in excess than the gravitational force by 3.3%. Therefore the centrifugal forces draw the waters to this side

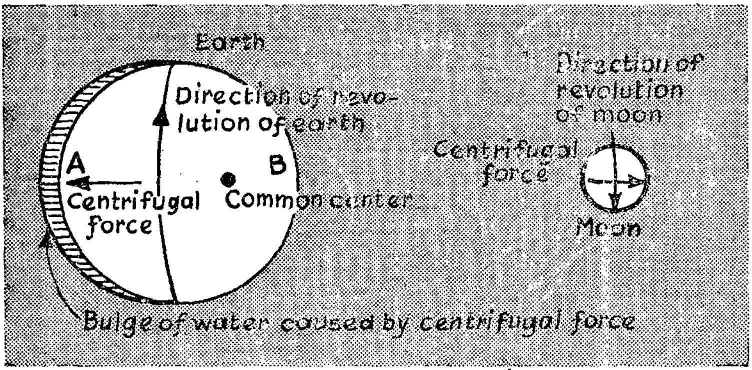

FIG. 33.2 Rotation of the Earth-Moon System

causing yet another bulge of water. These bulges are called the **high tides.** Water necessary for these bulges are drawn away from the sides which are at right angles to the moon. These regions will experience a fall in their water level. This is called **low tide.** Now as the earth rotates once these high and low tides also will be moving along keeping the moon at overhead position. The earth completes one rotation in 24 hours. Hence every point on the surface of the earth should experience two low and two high tides once in 24 hours. But as the moon also revolves round the earth two low and two high tides occur once in 24 hours and 50 minutes. These tides are called **semi-diurnal tides.**

Types of Tides

This type of high regularity in travel of tides is not possible because the earth's surface in the first instance is not a continuous expanse of water. Secondly the land masses which intervene are of different sizes and shapes. Therefore, the behaviours of tides are affected. Some places may experience only one high tide and one low tide in a day. These are called **diurnal tides.** They may both be found to occur in combination. These are described as **mixed tides.** These mixed tides may comprise of two high tides and two low tides.

Semi-diurnal tides are prevalent in equational regions and the diurnal tides in the high latitudes. The Indian and Pacific oceans generally experience mixed tides.

Spring and Neap Tides

Apart from the moon, the sun is the other celestial body influencing the earth in generating tides. The sun is 26 million times the mass of the moon. But it is 389 times away from the earth than the moon. Hence the tide producing force of the sun is only 46% as powerful as that of the moon.

When the sun, the moon and the earth are positioned in a straight line [Fig. 33.3 (a)] the tide generating forces of the moon and the sun act together causing larger tidal bulges. This happens during New moon and Full moon phases. This type of exceptionally great tides are called **spring tides.** But during the first and third quarter of the moon, the moon and the sun are positioned at right angles to the earth [Fig. 33.3 (b)]. At such time the tide generating forces of the moon and the sun are partially opposed to each other. This causes weaker tides called **neap tides.**

River Tides

Lower reaches of many rivers are subjected to tidal impulses During high tides, tidal waters enter the river and flow upstream against gravity and river flow. It moves slowly and in a wave form. This is called the **flow tide**. During periods of low tides water which has entered during high tide period flows down stream. It flows back faster because it moves downstream and also with the flow of the river. This is called an **ebb tide.**

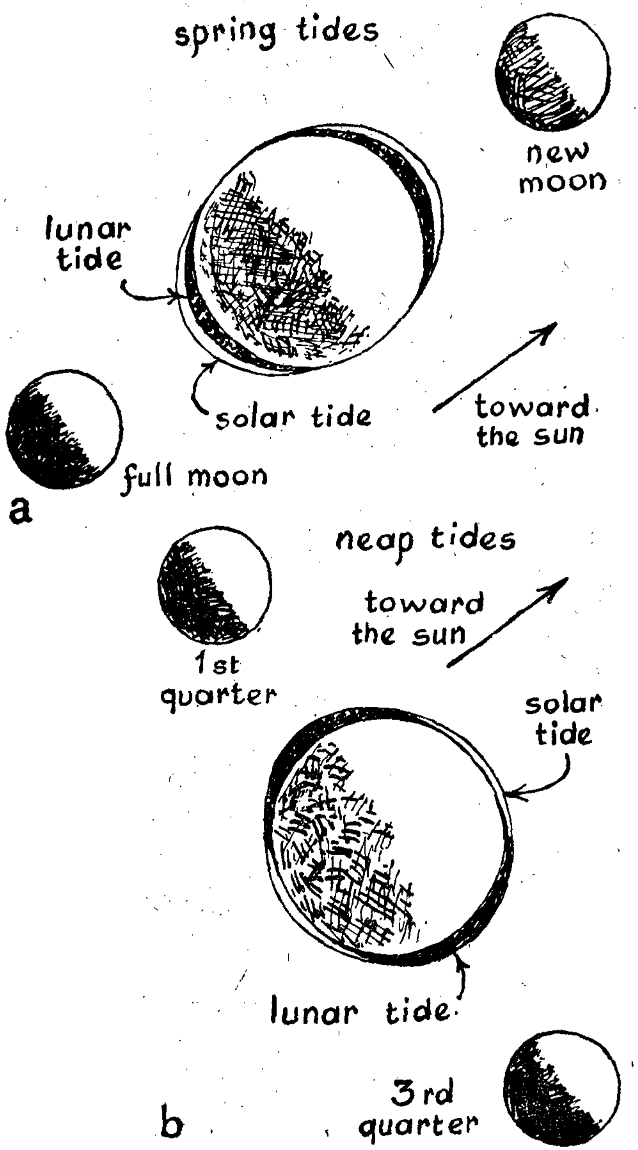

FIG. 33.3 Spring and Neap Tides

Tidal Bore

In the mouths of rivers and estuaries the incoming tidal wave may form an abrupt front of turbulant water. This is described as **tidal bore**. In a tidal bore the flow tide takes a steep and long wall-like form. Its proportions depend upon the characteristics of the incoming tidal wave, and the slope and shape of the channel. It is well formed during spring tide periods. Rivers like the Amazon, the Severn (England), the Yangtze Kiang and the Hooghly are known to develop well defined tidal bores.

QUESTIONS

I. Short answer questions :

1. Define a tide.
2. Define a spring tide.
3. What is a low and a high tide ?

II. Long answer questions :

1. How tides are caused ?
2. Explain the effect of sun on the ocean waters.

CHAPTER XXXIV

OCEAN RESOURCES

Sediments

Underneath the water, seafloor is found to have deposits of loose and unconsolidated materials. They vary in colour and in texture. They are called sediments. These **marine sediments** are derived from many sources. Materials are derived from the land, from the volcanoes and from the remains of dead animals, and other sea organisms.

Rivers and wind carry materials to the ocean. They are derived by the winds and rivers out of weathering. A greater proportion of marine sediments found on the continental shelf and slope are from land only. A large variety of plants and animals live in the sea water like the globigeunids, diatom, radiolarian, pteropods and coccolithophores. Their skeletons and waste materials settle down on the seafloor. Such sediments derived from this source is also largely found on the continental shelf and slope.

Fine dust particles and fragments fall from the sky. They are called cosmic dust. An estimated 10 to 100 million tons settle down into the sea water. These black and brown sediments are found in all parts of the ocean.

Volcanoes both on land and on the seafloor also contribute to the marine sidiments. These range from small boulders to fine ash. They are found to occur in submarine volcanic provinces. A large quantity of chemicals are also brought down by the rivers in form of solutions. On reaching the sea they precipitate into solid form and settle on the sea floor. Such sediments contain metal rich manganese modules and other minerals like pyrite, dolorite and aragorite etc,

Marine sediments are classified into two categories :

(1) Terrigenous (2) Pelagic

Terrigenous sediments are derived from the land. The Pelagi deposits belong to the deep sea.

The oceans are found to have varying thickness of sediments in them. The mid-Atlantic Ridge has sediments of 50 metres thick, whereas the Argentine Basin in South Atlantic has sediment of 3 km thick. Atlantic is found to have larger sediments than the Pacific and the Indian oceans. The seafloor sediments are believed to contain the complete record of the earth's history.

Food Resources

Like land, the sea also abounds in life. The marine life ranges in size from the microscopic organism to the largest whales. The oceans are estimated to contain 100,000 million tons of sea fish. They contain enormous quantities of protein. While half the humanity starves without food, the daily intake of man has only 1% of marine fish in it.

Generally fishes abound in coastal waters. Because the continental shelf areas are shallow and are rich in plant and animal food called planktons. The rivers bring in large quantities of nutrients and sufficient quantity of sunlight and air is also available here. Fishes have a tendency to spawn only in these shallow waters and on the banks off the coasts. Upwelling of currents near the coasts bring large quantities of nutrients to the surface.

Major Fishing Grounds

Even though all the coastal waters abound in fish, some of them are more favoured and are rich in fish varieties. They are the North eastern and North western coasts of North America, the seas of Japan, and the Dogger Bank of North Sea. All these areas are located in the temperate latitude. They are also regions where warm currents meet cold currents. This mixing of currents create a more suitable environment for the growth of more varieties of fish (Fig. 34.1)

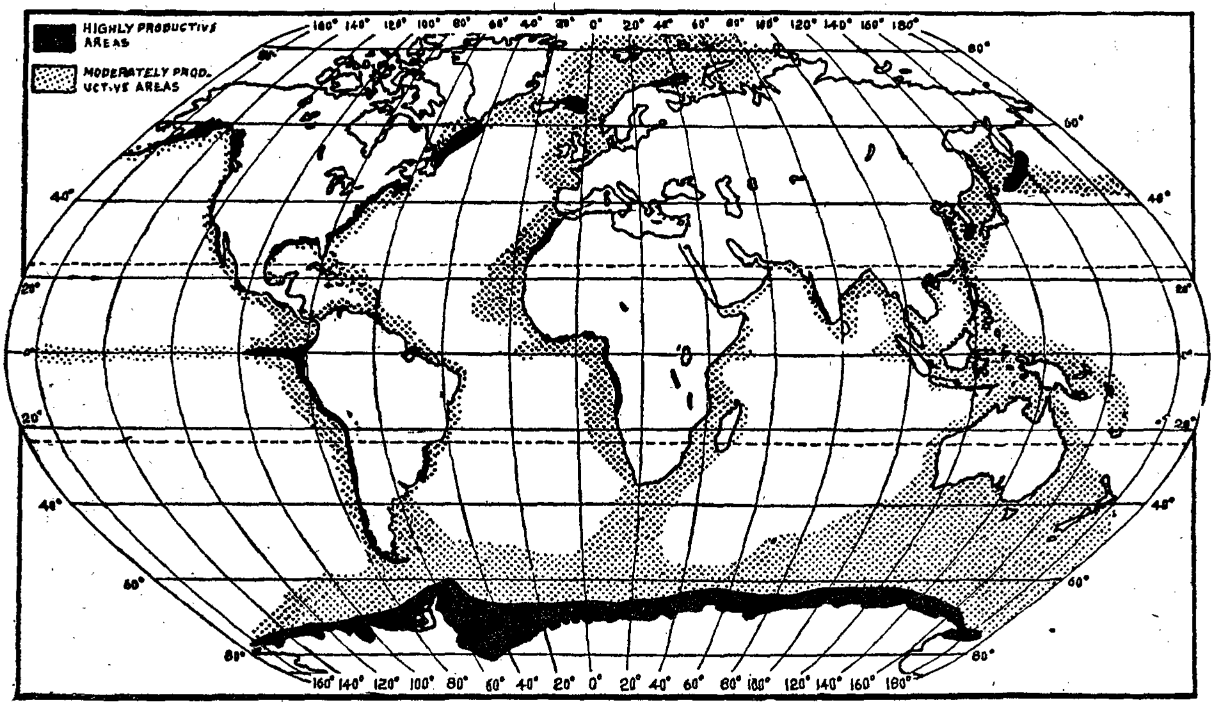

FIG. 34.1 Fishing Grounds of the World

The North Sea

This is the largest fishing area in the world. The famous Dogger Bank is a part of this fishing area. Herring, cod, mackerel and oysters are the important varieties caught here.

Japan

The seas around Japan are important fishing grounds because they are shallow and warm and cold currents meet and mix here. Sardines, Salmon, Mackerel and Herring are some of the varieties of fish harvested here.

The Grand Banks

This again is a meeting ground of Labrador cold currents and the warm Gulf streams. The Grand Banks extend to a distance of 500 km along the north eastern shores of North America. The abundant growth of plankton results in the proliferation of fish varieties Cod, herring and lobster are the important varieties available here.

North Western Coast of North America

This fishing ground borders the Pacific coast of Alaska, British Columbia and the United States. The mixing of cold and warm current promotes proliferation of fish varieties. Salmon, herring, cod and halibut are the chief varieties available here.

World Fish Catch

Peru stands first in the world in fish catching followed by Japan and U S.S.R. Marine fishing is estimated to bring in an annual income of 8 billion dollors. 53% of the total fish catch of the world is made in the Pacific ocean alone. The Atlantic and the Indian oceans yield 42% and 5% respectively.

Mineral Resources

The world ocean is endowed with an incredibly large quantity of mineral resources. Water by itself constitutes a resource. Many dissolved solids like sodium chloride (common salt) and mag-

nesium are extracted in large quantities at present. Besides these, numerous other resources occur on the seafloor as well as under the seafloor.

Water as a Resource

Today attempts are being made to convert sea water in a large scale for drinking and irrigation purposes. Besides, possibilities are being examined to utilize tides for the generation of electricity. One cubic km of sea water is believed to contain 39 million metric tons of solids like sodium chloride (common salt) and magnesium. It has also been proved to contain Rs. 8 billion worth chemical elements, including silver, gold and lead.

Deposits on the Floor

The deep seafloor has vast deposits of manganese modules. They are estimated to contain 24% of manganese 14% iron, 1% nickel and smaller amounts of cobalt and copper. A portion of south Pacific seafloor alone possesses 7,300 million metric tons of manganese modules per sq. km. Besides, phosphates, iron, etc., are the other minerals said to occur on the seafloor.

Resources under Seafloor

The continental shelf is of great economic potential because of the availability of petroleum, gas, and coal under it. One third of world' soil and gas is extracted from the off-shore oil fields. The world's continental shelf alone is supposed to have 250,000 billion barrels of petroleum under it. The South West coast of U.S.A., Coast of Borneo, Persian Gulf, Sea of Japan, Bombay High (off the west coast of India near Bombay) are some of the continental shelf areas where oil is extracted at present. Coal is another resource mined from under the seafloor. 10% of the British and 30% of the Japanese coal products come from the ontinental shelf areas of these countries.

QUESTIONS

I. Short answer questions:

1. What are the various sources of sediments in the ocean?
2. State the importance of oceans as a source of food.
3. Identify the major fishing grounds of the world.
4. What is a plankton?

II Long answer question:

Discuss the importance of oceans in changing world.

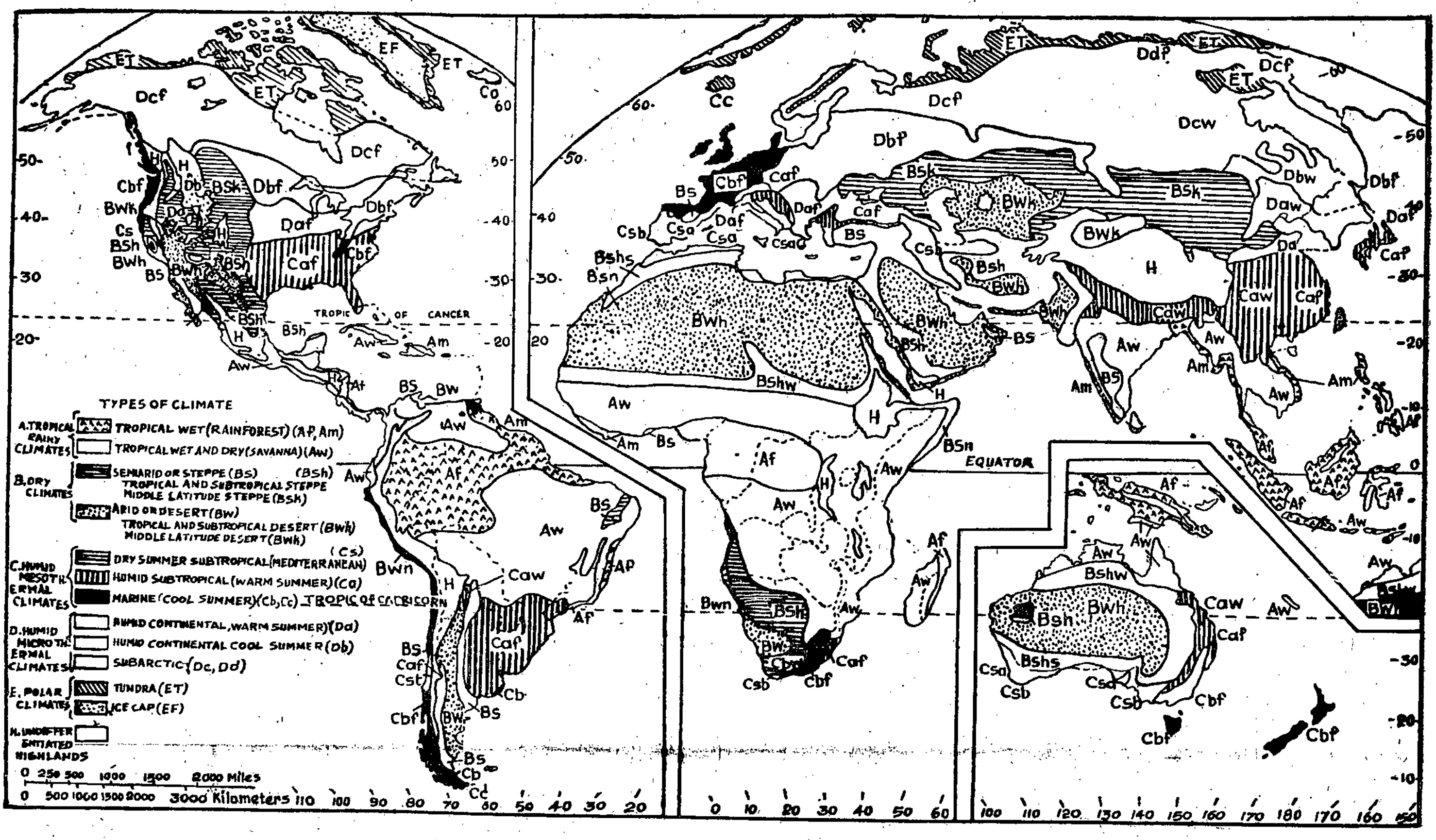

FIG. 15·2 Koppen's Classification of Climates

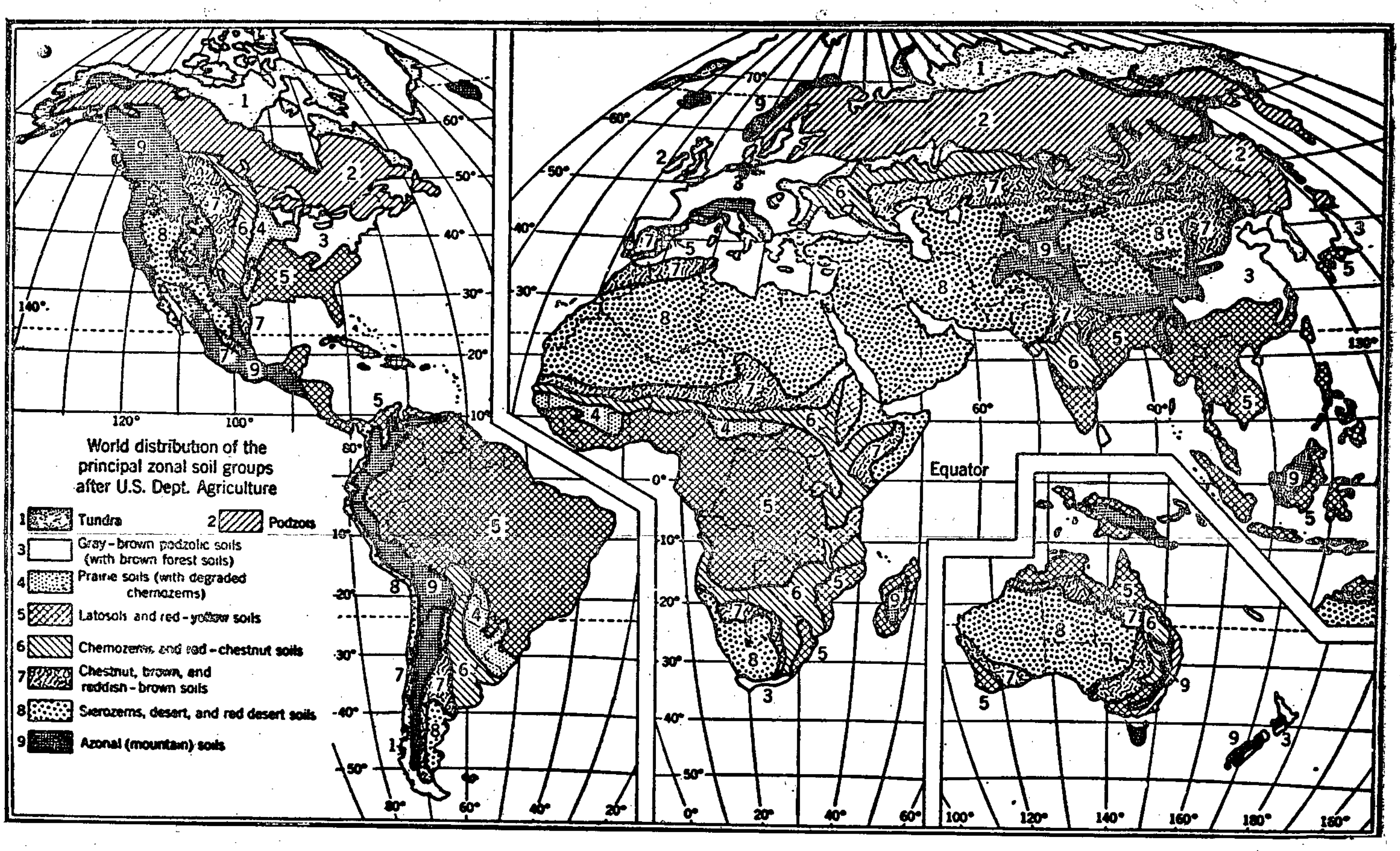

FIG. 25·3 Distribution of Major Soil Groups

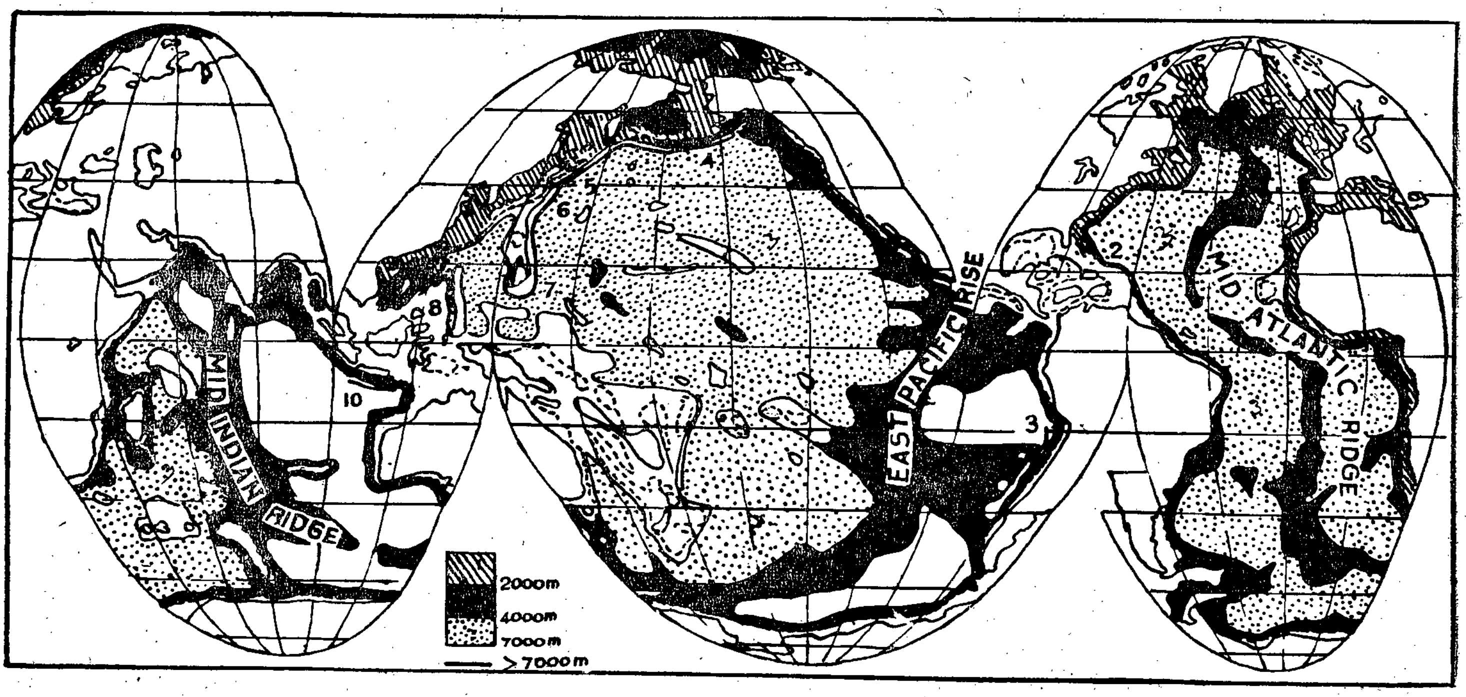

FIG. 28·5 Relief of Sea Floor—World

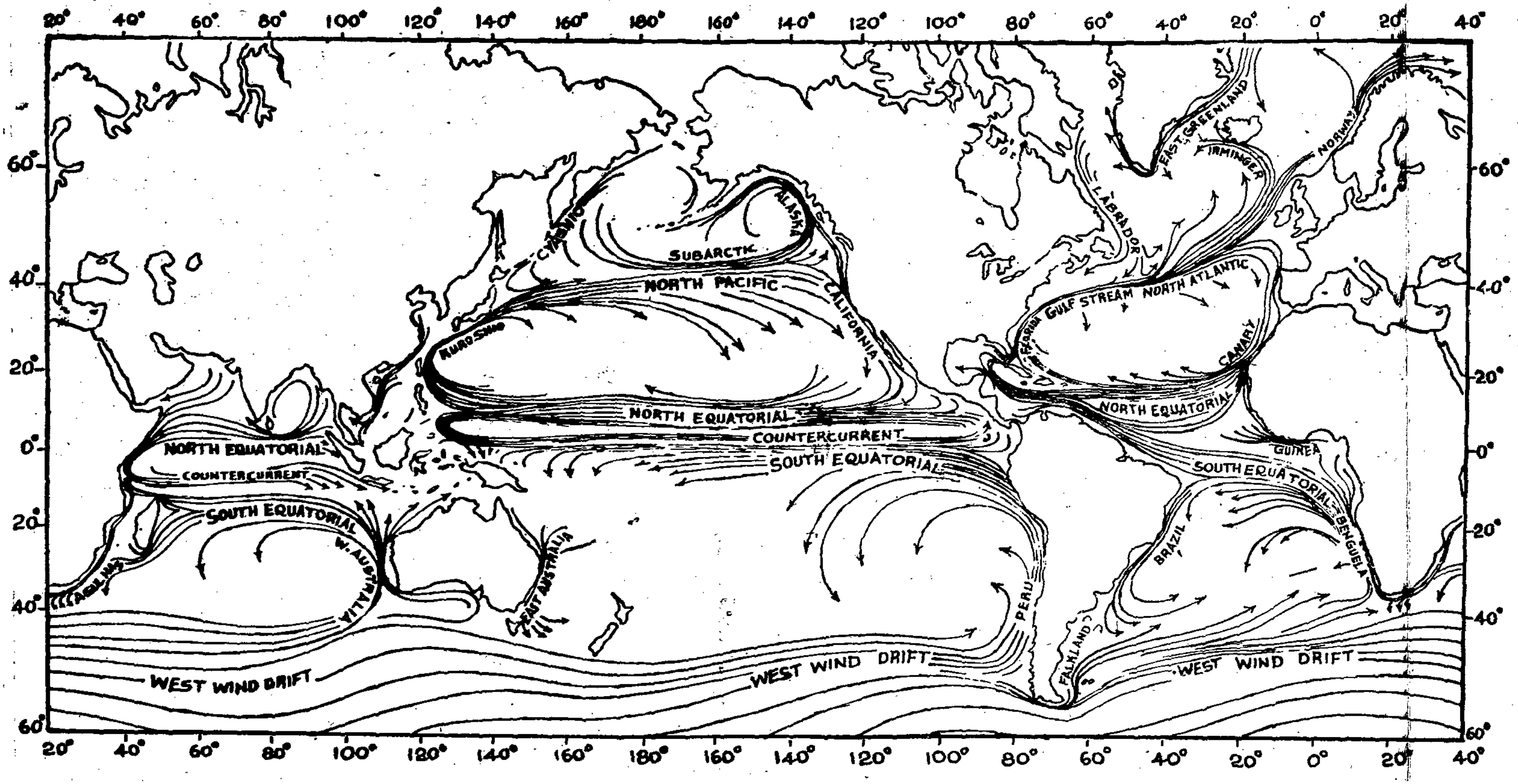

FIG. 31·2 Major Surface Currents of the World

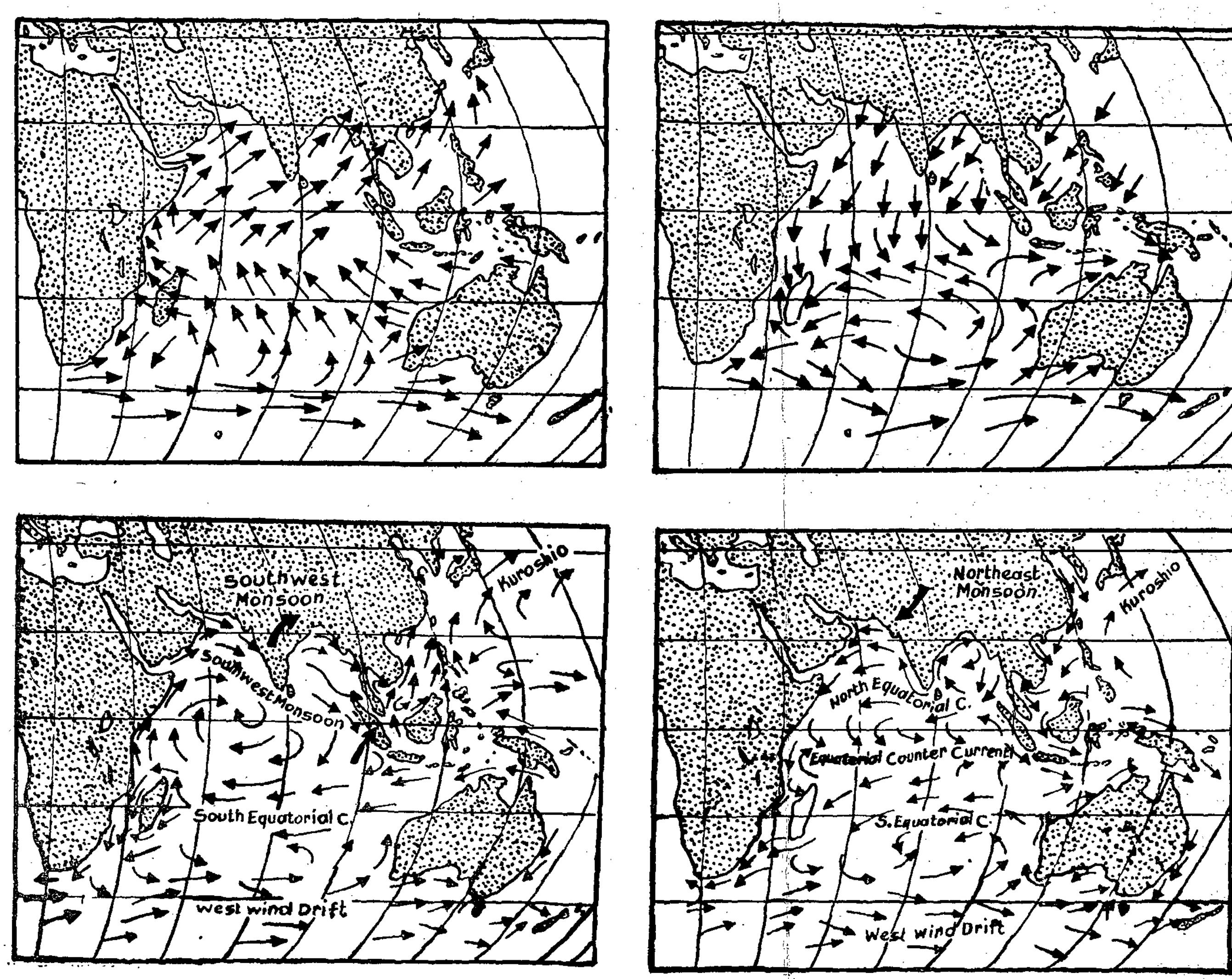

FIG. 31·3 Surface Currents in the Indian Ocean—Impact of Monsoon

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